REPORT

ON

INDUSTRIAL WASTES

FROM THE

Stock Yards and Packingtown

IN

CHICAGO

MADE TO THE BOARD OF TRUSTEES OF
THE SANITARY DISTRICT OF CHICAGO
OCTOBER, 1914.

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Made to the
ENGINEERING COMMITTEE of the SANITARY DISTRICT OF CHICAGO

GEORGE M. WISNER, Chief Engineer
LANGDON PEARSE, Division Engineer

LETTER OF TRANSMITTAL

Chicago, October 15, 1914.

To the Honorable, the Committee on Engineering.

Gentlemen:

For the past three years this Department has been making a careful study of the sewage and sewerage conditions of the region known as the Stockyards and Packingtown, which drains into the East and West Arms of the South Fork of the South Branch of the Chicago River. For the past two years a sewage testing station has been operated at the outlet of the Center Ave. sewer into which comes much of the sewage from the packing plants. The construction cost of this testing station was largely defrayed by a fund contributed by the various firms in Packingtown, the Union Stockyards and Transit Co. furnishing the land at a nominal rental. In consideration of this contribution a report was promised to the subscribers, which I now have the honor to present.

The report and estimates are necessarily preliminary. Before any actual construction work can be done, a detailed survey of the district and its sewers will be required and detailed plans prepared for treatment works. The legal phases of the situation require con-

sideration and the determination of who shall finance the work is all important. The report indicates methods of treatment which have been demonstrated, and points out the feasibility of handling the wastes from the entire packing and stockyards industry, so that eventually no load of that character would be put upon the main channel of the Sanitary District, if circumstances require.

The investigation clearly shows that the sewers now existing in the Stockyards and Packingtown are inadequate and need rebuilding. In view of the fact that the City of Chicago is proposing to construct a new sewer along Center Ave., the time is ripe to adopt a definite plan for a sewerage system and for sewage treatment of the industrial wastes of this section.

Our feeling has been that a community plant is desirable because of the concentration of the operation in one locality and consequent ease of securing the best and most economical operation. On the other hand, there is force in the argument that each firm would prefer to control its own waste. Yet some firms now operate recovery plants for grease on community sewers. Our conclusion is that fine screening is entirely feasible and advisable at each individual house or group of houses belonging to a firm, in addition to and following grease skimming. Screening should be supplemented by a sedimentation plant either at each house or preferably in a community plant.

The report covers many phases of the Stockyards and Packing industry and represents the combined work of the Sanitary Division, under the direction of Mr. Langdon Pearse, Division Engineer. To Dr. Arthur Lederer, Chemist, for investigation in the chemical and bio-chemical fields, and to Mr. L. C. Whittemore, Resident Engineer, for field supervision, compilation of the records and preparation of the report, due acknowledgment is made, as well as to the other assistants in both engineering and laboratory work who have carried out the work.

To the officials of the Union Stockyards and Transit Co., as well as of the packing houses, all of which firms are listed in Appendix I, thanks are due for hearty co-operation and assistance in carrying through the investigation.

In view of the injunction suit now pending in the Federal courts to determine our right to take diluting water from Lake Michigan over and above 4167 cu. ft. per sec. and the need of adjusting all improvements to the outcome of that case, I feel that the Board of Trustees should carefully consider this report and consult with the representatives of the interested industries, as well as the officials

of the City of Chicago, in order to agree upon a workable plan.

The organic law of The Sanitary District of Chicago is based on the theory that a channel will be constructed solely for the reception of domestic wastes. The Federal statutes distinctly prohibit the dumping or discharge of settling solids into any navigable water or tributary thereof. Under these authorities, it would be possible to close up absolutely every industrial establishment discharging wastes into the Chicago River or Drainage Canal. Undoubtedly, the law intends that the larger burden shall be carried by the industries. Improvement of existing conditions is imperative. In the present stress of finance and industries, time should be given to all concerned to look the situation squarely in the face and to decide what they will do. Certain improvements can now be made at moderate expense. Greater expenditures for further improvement can be met later. For many years Bubbly Creek has been a byword, but I hope soon with the co-operation of all concerned that it will become a memory.

Respectfully submitted,

GEORGE M. WISNER,

Chief Engineer.

REPORT ON INDUSTRIAL WASTES
FROM THE
STOCKYARDS AND PACKINGTOWN
IN CHICAGO

THE INDUSTRY, ITS UNITS AND ITS WASTES; TESTS OF TREATMENT, AND A PROJECT FOR THE IMPROVEMENT OF BUBBLY CREEK

For Details, see Chapters I to XVII following

SUMMARY.

GENERAL. Some two years ago, negotiations were begun with the firms in the Stockyards and Packingtown by which a testing station was put in operation at Center Ave. in September, 1912. Engineering studies were made on various alternatives for sewers in handling industrial wastes. It was early recognized that in such development some heed should be paid to the possible future requirements both for sewerage and sewage disposal, as the U. S. government has been seeking to enjoin the Sanitary District from diverting more than 4167 cubic feet per second from Lake Michigan. This suit is not yet decided.

Last year a movement was started to fill up Bubbly Creek, that is the west arm of the south fork of the south branch of the Chicago River. This would reclaim a certain amount of space, now useless, and would permanently remove from the vicinity of Packingtown the present river nuisance. Unless steps were taken, however, to reduce the organic load, this removal in itself would only transfer the present trouble to other localities.

WESTERN AVE. CONDUIT. In 1909 a conduit was built from the west end of the west arm of Bubbly Creek north to and along West 39th St. to Western Ave. and thence north to the Drainage Canal at 31st St. This conduit was expected to cause a circulation in the then stagnant west arm, by utilizing a slight difference of head. But continued use for over four years has not proven this adequate. Material settles in the west arm as markedly as before. A recent inspection of the conduit has shown deposits from two to four feet deep, due to low velocities, and a much reduced flow, at

present about 75 cubic feet per second, practically the flow of Western Ave. and Robey St. sewers plus Ashland Ave. In the present condition of the conduit, this flow appears largely independent of the working of the flushing pumps at 39th St. and Lake Michigan.

DREDGING. Dredging was carried out last year at a total expense of $34,534.05, of which the committee of packers and the stockyards paid $26,864.38. This affords, however, only temporary relief, since the dredged spots fill in again and all the while the deposits on the bottom become septic, blow up, form scum and give the disagreeable appearance from which the characteristic name, "Bubbly Creek," was derived.

TESTING STATION. The testing station investigations at Center Ave. have been extended beyond the original program, because certain additional experiments were found necessary to study the treatment of settled sewage on sprinkling filters and the behavior of devices under a longer trial than one year. Other special tests on sludge handling, recovery of fats and the like are still under way. The formulation of a new method of testing effluents early in 1914, by our Chemist, Dr. Lederer, also emphasized the need of learning at some length the comparative oxygen requirements of domestic sewage, as well as Packingtown wastes and other industrial sewage.

The original testing station layout (1912) was equipped with a coarse screen with $\frac{5}{8}$ in. clear openings, a 2 in. centrifugal pump, a grit chamber, Emscher tank and Dortmund tank. To this has been added a fine mesh (30 meshes to the inch) rotary screen of the Weand type, a sprinkling filter and a chemical precipitation tank with devices for mixing and applying chemicals. A screen testing device was also added, as well as sedimentation cans.

CRUDE SEWAGE. The sewage at both Center Ave. and Ashland Ave. outlets is very strong, containing large amounts of both suspended and soluble matter (cf. table 116). At different hours of the day, the crude sewage varies greatly in strength according to the discharge of wastes from the stockyards and Packingtown. The average analyses for the year 1913 for the day and night flow from Center Ave. sewer are given in table 9. The character of the night flow and Sunday flow was practically identical. Some seasonal variation in strength occurred, the sewage being weakest during the spring and summer and attaining a maximum strength during the late fall and early winter. The great strength of the day sewage is clearly shown by comparison with the purely domestic sewage from 39th St. sewage pumping station (cf. table 116). At Center Ave. a biologic oxygen consumption of roughly 1000 p. p. m. was

found for the crude day sewage, whereas at 39th St. this was only 100 to 150 p. p. m.

The temperature of the sewage at Center Ave. ranged from 60 deg. Fahr. in the winter to 90 deg. Fahr. in the summer, being nearly 20 deg. warmer than the domestic sewage at 39th St. (cf. fig. 11).

The average week day flow at Center Ave. sewer, gaged during 11 months in 1912-13, varied from 16.4 cu. ft. per sec. at night to 29.0 cu. ft. per sec. by day (cf. fig. 19), with a maximum recorded hourly rate of 105 cu. ft. per sec. during a rainstorm. The Sunday flow has averaged 14.1 cu. ft. per sec. Of this flow about 150,000 gal. per 24 hr. have been handled in the testing station.

SCREENING, COARSE. All the crude sewage used in the testing station passed through a bar screen with ⅝ in. clear openings. The retention of solid material was nominal, averaging about 90 lb. of moist screenings per mil. gal. with a moisture content of 82 per cent. The screenings are largely hair, coarse vegetable matter, guts and similar material quite foreign to domestic sewage. A coarse screen is requisite in any case to protect pumps and other devices.

GRIT CHAMBER. The grit chamber has been operated at velocities from 17 to 25 ft. per min. With a detention period varying between 50 and 70 sec., the suspended matter has decreased inappreciably, but a slight deposit of detritus, largely mineral, has occurred in amount about 0.02 cu. yd. per mil. gal., with a specific gravity of 1.3 and a moisture content of 44 per cent. The grit chamber has acted largely as a grease skimmer, from 5 to 1260 lb. of scum per mil. gal. having been removed, containing on an average about 75 per cent. moisture. Of the dry residue about 60 per cent. is ether soluble. This is, however, by no means a complete fat recovery, being less than 11 per cent. of the total fat. The collection is higher in winter than in summer.

TREATMENT IN SETTLING TANKS. Plain sedimentation was tried in both Dortmund and Emscher tanks, and chemical precipitation in a Dortmund tank. The Emscher tank, at first arranged for a downward and upward flow, was changed in March, 1914, to a straight horizontal flow tank.

A daily average of 49 to 69 per cent. of the suspended matter in the heavy day sewage can be removed by plain sedimentation in tanks of the Dortmund and Emscher vertical flow types with periods from 1 to 4 hours. The effectiveness of the vertical flow tanks of the Dortmund or Emscher type depends on low velocities. From 60 to

70 per cent. of the suspended matter can be removed in straight flow Emscher tanks with a period from 2 to 3 hours. Chemical precipitation will remove upwards of 80 per cent. of the suspended matter, using about 3.0 grains of iron sulphate and 5 grains of lime per gallon.

QUIESCENT SEDIMENTATION. Special experiments on quiescent sedimentation in a deep can, along the lines indicated by Steuernagel at Cologne, Germany, show a removal of 76 per cent. of the suspended matter in 2 hr., with 1100 p. p. m. present. Extended settling over 12 hr. indicates a removal of 79 per cent., which may be taken to represent the settling suspended matter. The results plotted in fig. 17, indicate higher removals than for similar experiments on 39th St. sewage.

DORTMUND TANKS. The Dortmund tanks have been operated at varying detention periods and velocities. The average removal of suspended matter is as follows (see also table 27):

Upward Average Velocity Ft. per Hr.	Detention Period Hours	Per Cent Removal Suspended Matter		Number of Months Averaged	Tank
		Day Sewage	24 Hour Sewage		
4.5	1.0	49	47	1	C
2.6	4.0	54	48	2	D
2.3	1.9	54	53	4	C
1.8	2.0	49	42	1	C
1.7	6.0	63	57	3	D
1.5*	3.0*	72*	67*	2*	C
1.1	4.0	69	65	3	C
1.0	10.0	80	72	1	D

* One month on raw sewage and one month on screened sewage in daytime.

These results show that in a Dortmund type of tank, both velocity and detention period are factors in the efficiency of removal of suspended matter. Low velocity is more important than a long period, as the same detention period gives greater efficiencies with the lower velocities. This is of great importance in determining the economy of this type of tank. For instance, with a velocity of 1 ft. per hr., the removal is considerably higher than with velocities of 2.5 ft. and over. As the settling efficiency depends on the velocity, and the capacity on the area multiplied by the velocity, high velocities are desirable from the viewpoint of economy, but undesirable from the standpoint of efficiency.

EMSCHER TANK. With the Emscher tank, the following results have been obtained (see also table 45):

Average Upward Velocity Ft. per Hr.	Detention Period Hours	Per Cent Removal Suspended Matter		Number of Months Averaged
		Day Sewage	24 Hour Sewage	
	ORIGINAL TANK. VERTICAL FLOW			
1.9	4.0	52	45	2.5
2.5	3.0	50	47	2.0
3.8	2.0	51	48	5.5
5.0	1.5	53	50	4.0
	REMODELED TANK. HORIZONTAL FLOW			
9.2*	1.9	61	58	2.3
6.0*	2.9	72	69	3.0

* Horizontal Vel. Ft. per Hr.

Less variation occurred for different periods and velocities than with the Dortmund tanks. The relatively high efficiency for the 1½ hr. detention period may have been influenced by the addition of scum baffles about that time, which retained considerable light floating material from passing off in the effluent. The disturbances incidental to "ripening" of the sludge digestion chamber, also interfered with the efficiency of the tank during the first few months of operation.

CHEMICAL PRECIPITATION. With chemical precipitation, using copperas or alum and lime, or alum alone, during the hours of strong flow, and plain sedimentation during the night, a reduction in suspended matter of about 80 per cent. was secured. The

Upward Vel. Ft. per Hr.	Detention Period, Hr.	Grains per Gal.		Per Cent Reduction Suspended Matter	
		Copperas	Lime	Day	24 Hour
3.3	3.0	5.5	10.3	76	72
3.3	3.0	4.5	10.2	80	77
3.3	3.0	3.5	9.9	84	79
2.2	2.0	3.3	8.6	78	74
2.2	2.0	3.5	5.1	67	68
2.5	4.0	3.5	5.1	79	70
2.5	4.0	2.4	5.2	82	74
2.5	4.0	5.2	5.5	72	65
1.7	6.0	4.9	6.0	77	..
2.6	4.0	2.4*	2.8	64	52
2.6	4.0	3.0*	0.0	73	66
2.6	4.0	1.9*	2.7	82	76
2.6	4.0	3.2*	0.0	80	76

* Alum used instead of copperas.

following figures show the results of individual runs (see also table 55):

The apparatus for mixing and applying the chemicals was somewhat crude. In a large installation at least 3 gr. per gal. of copperas and 5 of lime would probably be required. Lime is essential to obtain a floc with the copperas. With alum a floc was formed without the addition of lime but scum formation was excessive. The cost for chemicals alone was assumed at $0.50 per mil. gal. for each grain of lime per gallon, $0.65 for each grain of copperas, and $1.15 for each grain of alum. On the basis given, 3 gr. per gal. of copperas would cost $1.95 per mil. gal. and 5 gr. per gal. of lime would cost $2.50 per mil. gal., making a total chemical cost alone of $4.45 per mil. gal.

SLUDGE ACCUMULATION. The amount of sludge retained in the various devices varied considerably per unit volume for individual measurements, apparently due to fluctuations in water content, slight changes influencing the volume very markedly. The relative proportion of bottom sludge and top scum is also a factor of importance. The following figures, based on actual measurements, indicate the amounts of sludge found in cubic yards per million gallons of sewage:

Tank	Cu. Yd. per Million Gallons			Period of Observation
	Sludge	Scum	Sludge and Scum	
Dortmund C.....	3.1	2.7	5.8	June 24, 1913, to June 19, 1914
Dortmund D....	6.1	3.5	9.6	Sept. 16, 1912, to July 7, 1913
Emscher E......	6.8	1.3	8.1	Sept. 16, 1912, to June 1, 1914
Chem. Precip....	12.7	...	12.7	Aug. 28, 1913, to June 1, 1914

The figure for chemical precipitation is the average of individual runs, using copperas and lime, the others are cumulative averages over long periods. With alum instead of copperas, considerable scum formed, but those results are not included in the table. The scum accumulation in the Emscher tank is high because of the inclusion of the scum removed during the ripening period. At that time it formed in large amounts, but afterwards very much less accumulated. These figures were obtained with a uniform rate of flow through the tanks throughout the entire 24 hours. But as the day flow in the sewer is much greater than the average flow during the hours of flow when the sewage is strongest and consequently when deposition is greatest, in adapting these figures to actual de-

sign, operating conditions must be taken into account. For uniform flow the figures are correct, but for a variable flow through a given number of units allowance must be made for the greater proportion of day flow, in figuring the probable rate of sludge accumulation. On the other hand, the greater depth of the tanks in an actual plant would have a tendency to compact the sludge and thus diminish its volume.

The following table gives approximately the average composition of sludges and scum from the various tanks:

Tank	Specific Gravity	Per Cent Moisture	Percentage on Dry Basis			
			Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble
SLUDGE						
Dortmund C.	1.02	90.8	2.65	72	28	8.1
Dortmund D	1.02	91.7	2.88	76	24	8.6
Emscher	1.02	91.4	2.75	64	36	6.6
Chem. Precip	1.03	89.5	2.21	58	42	5.1
SCUM						
Dortmund C.	1.02	84.1	2.55	71	29	7.7
Dortmund D.	1.02	84.5	2.60	75	25	9.2
Emscher	1.01	84.1	2.73	72	28	12.9

The digestion in the Emscher tank is shown by the decrease in the proportion of volatile matter over the fresh Dortmund sludges. The influence of the precipitant on the chemical precipitation sludge is indicated by the high ratio of fixed matter. The scums are very similar to the sludges from the respective tanks, except that the moisture content is lower. The Emscher scum, however, shows an appreciably higher percentage of volatile matter, indicating that little or no digestion has occurred.

SCUM. Scum consistently persisted on the surface of the Dortmund tanks at all times. Practically none formed on the chemical precipitation tank, except when alum was used instead of copperas. For the first seven months of operation, scum formation was excessive on the Emscher tank. With the establishment of thorough ripening, however, the production of scum has shown a marked decrease, particularly during the summer months. Experiments on Tank C using the effluent from the rotary screen seemed to indicate that scum formation could be largely eliminated by preliminary fine screening through 30 mesh screens.

ODOR. Slight odor developed from the Emscher tank. A trace of hydrogen sulphide was occasionally noted, particularly when sludge was being removed. With the other tanks, the odor has been more marked, particularly during removal of sludge.

SCREENING, FINE. A number of experiments were conducted on the efficiency of fine mesh screens of mesh from 4 to 40 per lineal inch. In most cases the flow was 14,800 gal. per 24 hr. per sq. ft. of screen area, on a screen approximately 3.5 sq. ft. in area, on strong day sewage running to a final loss of head of 4.5 ft. From 134 to 1534 lb. of dry material was removed per mil. gal. (table 86), with a calculated per cent. reduction of suspended matter ranging from 10 to 26 per cent. The removal by the 24, 30 and 40 mesh screens averaged from 1098 to 1534 lb. of dry material per mil. gal. 60, 80 and 100 mesh screens tested subsequently gave somewhat higher per cent. removals of suspended matter, but as the sewage at that time was weaker the pounds of dry material removed per mil. gal. was less than for the former screens previously tested (cf. tables 85, 86). These results indicate in general an increasing efficiency with decreasing size of mesh, under similar conditions.

REMOVAL BY FINE MESH SCREENS.

No. Meshes per Lineal Inch	Net Length of Opening Inches	Dry Screenings Lb. per Mil. Gal.	Suspended Matter Per Cent Reduction	No. of Tests
4	0.198	134	..	3
6	0.137	654	13	5
10	0.072	421	10	6
16	0.042	992	17	4
20	0.036	919	16	4
24	0.029	1113	21	5
30	0.022	1098	19	10
40	0.015	1534	26	11

ROTARY SCREEN. Extended experiments were also made with a small rotary screen of the Weand type 2 ft. 4 in. in diameter and 4 ft. 8 in. long, swung on a steel axle. The coarse supporting screen was covered with a fine screen of 30 meshes per lineal in. The screen rotated 7 r. p. m. and was cleaned by a spray of water directed against the outside, the screenings being ejected at one end by a worm and buckets. During three separate runs, in October, No-

Date	Hrs. of Operation	Dry Screenings Lb. per Mil. Gal.			Per Cent Reduction Suspended Matter Computed		
		Max.	Min.	Avg.	Max.	Min.	Avg.
Oct.-Dec., 1913	8:00 a.m. to 4:00 p.m.	1420	505	950	23	12	17
May, 1914	7:30 a.m. to 10:30 p.m.	816	304	500	16	6	12
May, 1914	10:30 p.m. to 7:30 a.m.	41	26	32	..	..	..
July, 1914	8:00 a.m. to 11:00 p.m.	488	194	319	12	6	9

vember and December, 1913, May, 1914, and June, 1914, each of about one month's duration, the foregoing results were obtained.

Based on the actual analyses, the average reduction of suspended matter for the first run was about 32 per cent., as compared with the average of 17 per cent., computed by the addition of the weight of screenings to the effluent. The result of operation during the heaviest hours of the day is strikingly shown. Extending the period of operation into the evening cuts down the unit rate of accumulation, while the removal at night is comparatively low. The capacity of the screen was not found to be exceeded with rates of flow between 5300 and 8000 gal. per day per sq. ft. of net effective area, at the linear peripheral velocity of 51 ft. per min.

SCREENINGS. The material caught by the screen differs widely in appearance from the tank sludges and scums, and is usually of a dirty greenish yellow color, firm enough as ejected to be forked after slight draining. The material is largely organic, the volatile matter in the dried residue running uniformly over 90 per cent. When delivered from the screen, the moisture content averages between 85 and 88 per cent., but after slight draining is readily reduced to about 80 per cent.

SCREENS ON STOCKYARDS AND PACKING HOUSE. Beside the work at the testing station, additional tests were made on a traveling band screen designed by Mr. C. A. Jennings, located at the outlet of the Morgan street sewer, and also on a Weand screen, purchased by the packers, and installed at the Sulzberger plant. The Morgan street sewer receives drainage from a portion of the stockyards only. The sewage is considerably weaker than the ordinary packing wastes (cf. table 116). The Sulzberger screen was set up at the outlet for the entire plant. Both these screens were covered with wire cloth with 40 meshes per lineal in. when tested. The duration of each test at Sulzberger's was from 1 to 7 hr. (cf. table 82), according to circumstances, and from 5 to 6 hr. at Morgan St. The results of these tests are tabulated below:

Sewer Outlet	Dry Screenings Lb. per Mil. Gal.			Per Cent Reduction Suspended Matter			No. of Tests	Screen
	Max.	Min.	Aver.	Max.	Min.	Aver.		
Morgan St...	1420	945	1150	49	22	33	5	Jennings
Sulzberger ..	2820	320	1690	39	8	26	7	Weand

The initial content of suspended matter delivered to the Jennings screen averaged 340 p. p. m., whereas that at the Sulzberger

plant averaged 747 p. p. m. Considerably higher efficiencies are probably possible at the individual plants than can be obtained at the Center Ave. outfall, largely because of the greater concentration and freshness of the wastes. Although no tests were made by the District at the Armour plant, an average efficiency of about 65 per cent. was claimed by their superintendent, Mr. Harding. This appears very high, but may be influenced by concentrated waste from certain processes, as for instance, water from the paunch manure presses containing considerable coarse material in suspension.

An essential requisite of a good screen is its equipment with adequate cleaning devices. Water was used on the screen at the testing station and compressed air on the Jennings screen. Both were effective, but the high pressure at which the air was then applied resulted in rapid destruction of the wire mesh. The presence of large quantities of grease or fat in the sewage is likely to cause more or less clogging, by depositing or chilling in the meshes of the screen. This can be removed by occasional application of steam.

At Morgan St. the 40 mesh screen removed from 4820 to 7860 lb. per mil. gal. wet material, averaging 6740 lb. or 1150 lb. dry. This removal averages about 24 per cent. actual suspended matter or a computed removal of 33 per cent. The previous summer a small straight flow tank of 1.21 hr. capacity removed 3.8 cu. yd. of sludge per mil. gal of 88.5 per cent. moisture. The removal of suspended matter averaged 63.8 per cent., with an average of 548 p. p. m. in the influent. This yardage is probably low because the tank unloaded at times. The sludge had an offensive putrid odor. Based on the removal of suspended matter, the sedimentation plant is far more effective than screening.

SCREENS WITH TANKS. As an adjunct to tank treatment, fine screening is likely to prove useful. The removal of light scum-forming material from the influent to the tanks is desirable in reducing operation difficulties and increasing the clarity of the effluent. During the months of May and July, 1914, one tank was operated on screened sewage during the daytime, and maintained almost an entire freedom from scum throughout the month. Under ordinary operation, a heavy scum would have formed long before the end of the month. The reduction in amount of sludge handled is also desirable under the conditions existing in the yards. Screenings at the rate of 500 lb. of dry material per mil. gal. would represent a reduction in volume of nearly 3 cu. yd. of sludge containing 90 per cent. moisture, or about 2 cu. yd. of scum containing 85 per cent. moisture.

SLUDGE HANDLING. The handling of the liquid sludge pro-

duced by settling tanks is one of the important factors in reaching a conclusion. The rate of accumulation of sludge from the various devices was large and the composition largely organic.

When withdrawn from the tanks in bulk, the moisture content was always greater than that *in situ,* as the withdrawal of some of the overlying sewage appeared almost inevitable, on a small scale. This increased the volume to be handled. The sludge from the various devices differed in appearance. That from the Emscher tank was uniformly black and even grained, flowing readily, and had little or no odor. The fresh sludge from plain sedimentation was usually of a dirty greenish black color, frequently having a very offensive odor. The consistency when run from the tank was not uniform, sometimes being very thick, while at other times quite thin. The chemical precipitation sludge was usually of a dirty greenish black, or deep black color, sticky in consistency, and ordinarily had a peculiar sickish or metallic odor. The sludge from the secondary settling basin was usually of a deep brown color, very smooth in appearance, with an odor resembling that of decayed vegetables.

SLUDGE DRYING. Experiments on underdrained sand beds showed that the Emscher tank sludge uniformly dried to a spadeable condition in layers 1 to 1.5 ft. thick in 5 or 6 days of good weather. Under these circumstances, the moisture content was ordinarily reduced to about 75 per cent. Although the sludge was still moist it was removed from the beds without difficulty. With fresh Dortmund sludge dried under similar conditions the drying time varied from 2 to 4 weeks with a final moisture content of about 75 per cent. The chemical precipitation sludge was even more retentive of moisture, 3 to 4 weeks usually being required.

The Emscher sludge drained largely from beneath. Within 24 hr. after application, the surface became firm and cracks began to appear. With the fresh sludge, the water ordinarily flushed to the surface, making the drying largely a matter of surface evaporation. The chemical precipitation sludge was very retentive of moisture, a thin hard crust forming on the surface while the interior of the mass remained soft and sticky for long intervals. Violent septic action was sometimes noted in this sludge after application to the beds, the surface sometimes falling 6 in. on the stirring of the mass, by the liberation of entrained gases.

Little has yet been done on the secondary settling basin sludge, but the indications are that it will dry very readily in thin layers.

The beds used in these experiments were about 6 in. deep, con-

sisting of graded gravel overlaid with about 1 to 2 in. of torpedo sand. They were exposed to the sun and air.

SLUDGE PRESSING. A few experiments were made with a Kelly filter press, using the chemical precipitation and fresh sludges. Sludge was pumped into the press under pressures of from 70 to 80 lb. per sq. in., which were maintained for about 15 min., the filtrate escaping through the press cloth. Irrespective of the initial moisture content, a final result of about 75 per cent. was obtained in most cases. The sludge appeared wetter than that of similar moisture content removed from the beds, being more compact. One objection to this type of apparatus was found to be the frequent rehandling of sludge necessary, as the cloths became completely clogged after a thin "cake" had formed over them. The interior of the press was left filled with liquid sludge which had to be withdrawn to allow the cloths to be cleaned.

SLUDGE FUEL VALUES. Calorific tests showed various sludges to have thermal values varying from 2500 b. t. u. per lb. for dried sludges, which had been exposed to the weather for several months, to over 9000 b. t. u. per lb. for fresh sludges and screenings on a dry basis. The fresh material, if rapidly dried, has a calorific value comparable to that of poor coal when computed on a dry basis. A considerable portion of these heat units must, however, be used in evaporating the moisture content. A considerable loss of heat-producing constituents occurs, however, on protracted exposure to the air. The great bulk of water which the fresh sludges contain is the chief obstacle to their incineration.

FERTILIZER VALUES. The few analyses for fertilizing constituents made do not promise recovery of any fertilizer values worth attention from a standpoint other than possible reduction of sludge volume.

SPRINKLING FILTER. The filter was 6 ft. in depth, consisting of 5 ft. 6 in. of 1¼ to 2 in. limestone overlying 6 in. of 2 to 4 in. stone. It was dosed with a Taylor circular spray nozzle with a cam device for regulating the head on the nozzle. The effluent from the Emscher tank was applied to the filter. Operation began in September, 1913, at a nominal rate of 0.75 mil. gal. per acre daily and this rate was maintained till April 1, 1914, when it was increased to 1 mil. gal. per acre. On August 1, the rate was still further increased. These rates are actual net yields.

The work of the filter was very satisfactory. Suspended matter varying between 70 to 210 p. p. m. was applied, the removal varying from about 45 per cent. to an increase of 76 per cent. during

the unloading period in April, 1914. Nitrification became well established within a few days after the start and has been well maintained since, the nitrates in the effluent varying from 10 to 20 p. p. m. on the average.

Putrescibility and dissolved oxygen samples were taken four times daily at 3 a. m., 9 a. m., 3 p. m., and 9 p. m. The former were incubated at room temperature for 10 days.

For the entire period of the operation of the filter an average relative stability of 73 was obtained. But during May, June and July, the stability was 94. The time required to ripen, and the spring unloading in April lowered the stability for the first six months. There appears little doubt but that a rate can be maintained of net yield of 1 mil. gal. per acre per 24 hr. on a bed 6 ft. deep, with good results, giving practical stability once the filter has ripened.

The performance of the filter was best emphasized by the reduction in oxygen requirements. Approximately 1000 p. p. m. of oxygen were required for complete stability of the crude sewage from Center Ave., whereas the average requirement for the filter effluent was about 64 p. p. m. or a reduction of over 90 per cent. The filter effluent contained enough oxygen available to meet this requirement during the past 3 months and was stable. These figures were for the strong day sewage. Free oxygen was nearly always present in the filter effluent which was uniformly clear. The material in suspension discharged by the filter was granular, settling readily.

The indications are that a sprinkling filter can handle this liquid and produce an effluent remarkably improved over the original sewage. Continued operation is needed to settle the question of permanency of capacity. There is evidence that more or less fat is retained at times in the filter. Whether or not this will be removed during the unloading period is a question. Owing to the high temperature of this sewage, cold winter weather is not likely to cause any difficulty in operation.

SECONDARY SETTLING. The effluent from the filter was passed through a small secondary settling basin operated on the Dortmund principle. The detention period was 1 hr. the greater part of the time, and the upward velocity from 2.4 to 3.5 ft. per hr. Under these conditions, the removal of residual suspended solids varied from an increase of 7 per cent. to a removal of over 50 per cent., based on monthly averages. A longer period and lower velocity is evidently required. Sludge accumulated at a rate vary-

ing from 0.5 to nearly 8.0 cubic yards per mil. gal. between individual measurements. The percentage of volatile matter in the sludge recovered from this tank was appreciably lower than for the fresh sludges from the preliminary tanks, while the nitrogen content was distinctly higher.

Secondary settling basins appear desirable on account of the large amounts of suspended matter applied to the filter and unloaded. Owing to the excessive scum formation at times and the comparative difficulty of maintaining single chamber tanks, a double-deck type of tank seems preferable, even though a shallow sludge chamber necessitates pumping the sludge into the deeper primary settling tanks.

OXYGEN REQUIRED. Comparison of the total oxygen required for the oxidation of the sewage showed a demand at 39th St. on domestic sewage, of about 100 to 150 p. p. m., whereas at Center Ave. the demand was around 1000 p. p. m. The improvement by plain settling of the Center Ave. sewage averaged from 18 to 48 per cent. For chemical precipitation the improvement ranged from 22 to 48 per cent. The sprinkling filter did not at all times deliver a stable effluent, particularly at the start. However, during May, June and July, 1914, the oxygen available in the effluent was greater than the demand, so the liquid proved thoroughly stable, for the specific tests for biologic oxygen consumed. The larger number of relative stability tests made check very closely, with an average relative stability of 94.

The indications are clear that fine screening had a small effect on improving the stability of the liquid, compared with the improvement due to sedimentation.

FAT REMOVAL. While considerable fat is and has been removed by the skimming basins of the various packing houses, and on the Center Ave. and Ashland Ave. outlets, there is a loss due to insufficient basin capacity. The fat contained in the sediment or sludge is also lost, as well as the fats which are kept in an emulsified state in the hot summer sewage, by the heat of the liquid.

The studies on fat removal show a greater removal in the winter than the summer. This is not explicable on the theory of lack of business in summer, but probably depends on temperature. The melting point of the fat extracted by ether from the fatty wastes collected by us is 26 deg. C. or 79 deg. F. In the summer months the sewage is continuously warmer in the day. Cooling the sewage by exposure to air in shallow basins, or artificially, seems to be the

probable solution of this problem. About half the fat was removed on the average by plain sedimentation, while with chemical precipitation about two-thirds was deposited.

RECOVERY OF FAT BY ACIDIFICATION. Although there is considerable fat reported in the sludges as directly ether soluble, yet the acidification of the sludge will in many cases greatly increase the fat yield. Several random analyses are given on both sludge and scum:

Tank	Material	Ether Soluble Percentage of Dry Weight		Remarks
		As Removed	Acidified	
C	Scum	11.4	23.3	Chem. Pre.
D	Sludge	7.4	10.0	Bottom Sludge.
C	Sludge	10.0	25.6	....
Grit Cham.	Scum	62.3	69.0	....
E	Scum	12.6	29.8	From Gas Vent

Acidification of the heavy day sewage followed by sedimentation for 3 hr. in a Dortmund tank gave an average fat removal of about 69 per cent. The amount of acid consumed is large, 2,500 lb. of 100 per cent. sulphuric acid per mil. gal. being necessary to neutralize the alkalinity, while for efficient fat removal an excess is required.

Acidification of the sludge removed by plain sedimentation with subsequent recovery of the grease by the use of some solvent or by distillation with steam is also a possibility. The processes and costs are not as yet established.

Various ways have been suggested of acidification, which if ever proved economical, can readily be added to settling works. Acidification of sewage makes an apparent reduction in the biologic oxygen consumption which is remarkable, but this is probably not real, being simply due to a retardation of decomposition by the sterilization of the bacteria present, the organic material being left in solution. If thoroughly seeded, new bacteria will pick up the work of decomposition, the liquid then proving putrescible. Similar phenomena may happen with chloride of lime.

GENERAL CONCLUSIONS. The operation of the Center Ave. testing station has demonstrated that it is entirely practicable to treat to any desired degree sewage, mixed from industrial and domestic origin, as it issues from the Center Ave. outlet. Of the devices tried, fine screening, sedimentation in double-deck tanks, and sprinkling filters appear most suitable. The combinations are:

1. Fine screening.
2. Fine screening in combination with sedimentation.
3. Fine screening in combination with sedimentation followed by biological treatment on sprinkling filters and secondary sedimentation.

Under any circumstances, the removal of settling suspended matter from industrial wastes is needed. Fine screening alone does not appear adequate to meet this test. In almost every case screens can be installed at the individual houses, and on the fresh sewage will undoubtedly be more effective. Hence screening appears to be an individual problem for each house or firm. Sedimentation requires more space, both for equipment and disposal of sludge, and hence is best handled as a community problem, because at most houses space is lacking.

In any case, fine screening is the logical first step, to remove the coarser suspended matter, and will fit with sedimentation in that it materially reduces the scum-forming material.

Ultimately biological treatment of industrial wastes is a necessity. Sprinkling filters followed by secondary settling tanks seem most desirable. But with a gradual installation, opportunity is afforded on a large scale to watch the effect of the removal of suspended matter from a gross source of pollution. Preliminary screening and settling are necessary as a preparatory treatment for sprinkling filters, and would be advantageous in the operation of a long intercepting sewer by preventing deposits from a sewage so heavily laden with settling suspended matter.

OBJECT OF INVESTIGATION. The purpose of the investigation has been two-fold, first to learn how to relieve the load upon the main channel coming from the organic waste of this industry and second how to remove the local nuisance from the East and West arms of the South Fork of the South Branch of the Chicago River, and particularly the West arm, known popularly as Bubbly Creek.

CONSIDERATIONS INVOLVED. The solution of the problem involves not only a consideration of the municipal and private sewers in and around the yards and Packingtown, but also the efficiencies of various forms of treatment, the size and location of treatment works, and the relation of different steps in the collection and treatment to the future. Whatever is done must be flexible, readily adapted to future extension and fitting into a comprehensive system, if it ever becomes necessary.

EXISTING SEWERS. The present system of private sewers

in Packingtown is generally inadequate for flood flows. Center Ave. sewer is also overloaded at time of heavy rain. The City of Chicago is now planning a new sewer, located to the west of but parallel to the Center Ave. sewer, to run south and relieve the old Center Ave., Ashland Ave. and Robey St. sewers, and pick up some new territory.

EXISTING TREATMENT. At present there is practically no treatment of the industrial sewage from Packingtown, other than a partial removal of fat by grease skimming basins. The basins are seldom built to retain settling material, except at the hog-houses, and then are insufficient. The screens in use are very coarse and hold back little except intestines.

At the stockyards, the Jennings screen is handling the outflow of the Morgan St. sewer. At the other outlets no treatment is given.

FILLING BUBBLY CREEK. From the sanitary standpoint the filling of Bubbly Creek would be desirable, although mere filling alone would simply transfer the nuisance from one locality to another. With suitable treatment of the industrial wastes, it is entirely proper that this dead arm be filled and that the area thus reclaimed be used as a site for sedimentation tanks. The areas reclaimable are:

A. From the end of the West Arm to Ashland Ave.—11.5 acres.

B. From the end of the West Arm to W. 39th St.—16.5 acres.

C. From the end of the West Arm to the Forks—24.3 acres.

The fill required can be obtained in part from the construction of the proposed Center Ave. sewer, the proposed sedimentation plant, and from the dumping of ashes. The sedimentation plant itself for industrial wastes only will require 6 acres, and a reservation of 3 acres for future use.

The points to be cared for are:

1. The flow in the West 39th St. conduit should be increased, by the introduction of the sewage from Robey St. and industrial sewages from the East thereof, including the stockyards and Packingtown.

2. The sewage from the stockyards and Packingtown should be treated by fine screening and sedimentation at once, regardless of the outcome of the Federal suit.

3. A portion of the bed of the West Arm should be reserved for the sedimentation plant.

4. Intercepting sewers will be required to collect the

sewage and to divert the wastes of Packingtown from the new Center Ave. sewer into Ashland Ave.

BEST PROJECT. Consideration of various alternatives (see Chap. XVII) leads to the belief that the best project comprises an intercepting sewer for industrial wastes and domestic sewage extending from Halsted St. to the west end of the West Arm, the diversion of all Packingtown sewage from Center Ave. sewer to Ashland Ave. sewer, fine screening at the individual houses or firms, sedimentation at the outlet of the intercepting sewer, in a community plant built in the bed of the West Arm west of Ashland Ave., an outfall sewer into the West 39th St. conduit, receiving the effluent of the plant, and the diversion of the Robey St. sewer into the same conduit. The cost of this project is approximately $985,000, exclusive of legal, engineering and land expenses. The new Center Ave. sewer, under this project, would receive no industrial waste from the stockyards or Packingtown.

Such a project for screening and sedimentation handles the wastes as separately as possible, with the presence of some domestic sewage, and is flexible with regard to the future.

The ultimate solution will require biological treatment. As space is lacking in the immediate vicinity of Packingtown, this means an extended intercepting sewer running westward from the outfall of the sedimentation plant, which would carry the screened and settled sewage to a pumping station where the sewage would be pumped onto sprinkling filters. The effluent would require settling in secondary settling tanks. Sludge drying beds, an outfall sewer, and other collateral works are required. This fits directly onto the settling plant, just described. Screening and sedimentation are necessary as a preliminary treatment, and will materially aid in maintaining the intercepting sewer free from deposits. The additional cost for the intercepting sewer, pumping station, sprinkling filters and collateral works is approximately $3,600,000, exclusive of legal, engineering and land expenses.

BURDEN OF COST. There are many preliminary questions to be solved of legal and financial nature, as well as engineering details, before construction can commence. Particularly important is the distribution of the burden of cost. Undoubtedly the law intends that the larger burden shall be carried by the industries, for the organic law of the Sanitary District is based on the theory that a channel will be constructed solely for the reception of domestic wastes.

RECOVERIES. The results of the testing station do not indicate hope of recovering much material of value, from the commer-

cial standpoint, other than grease. It is possible that use may be found for the sludge as filler for fertilizer, and that the screenings may be burned. The smaller houses should endeavor to save all offal or other material now reaching the sewers, which is saved by the larger houses, by some cooperative arrangement.

The chief object to attain here is not commercial recoveries, but the destruction of a nuisance of long standing. Improved conditions of sanitation, and standards of civic cleanliness demand this.

CHAPTER I.

THE STOCKYARDS AND PACKINGTOWN INDUSTRY.

For years Chicago has been the center of stockyards and packing interests. A large community of plants has grown up in the vicinity of 39th and Halsted streets on the South Side, occupying over one square mile, with stockyards and packing houses, and including all the scattered plants, nearly one and one-half square miles. The industry has grown from small beginnings, with various shifts in location. In 1848, John B. Sherman started the Old Bull's Head stockyards at the corner of Madison street and Ogden avenue. This site proving unsatisfactory, a new site was selected at Cottage Grove avenue and 30th street, known as the Sherman Stockyards. In 1865, the site was again changed to a half-section bounded by 40th and 47th streets, and by Halsted street and Center avenue, at that time largely a swamp far outside the city limits. At first, the yards covered 120 acres, with 2,000 cattle pens, which grew in 1901 to 340 acres with 5,000 pens.

From 1865 on, the industry developed in one central location. As nearly as can now be learned, drainage was into the south branch of the Chicago River, a very sluggish stream, utterly inadequate to receive the wastes of even a young industry. Complaints began early and continued for years, lessened somewhat by the endeavors of the packers to recover more completely the by-products. In the early days, the problem of disposing of the offal resulting from the slaughter of cattle, sheep and hogs, was very troublesome. Even its value as fertilizer was unknown. Blood was allowed to run into the river, while heads, feet, tankage and general refuse were hauled out on the prairie and buried. A few began to dig up this material, and convert it into glue, tallow, oil and fertilizer in small factories. For awhile the offal was given to any one who would cart it away. Various products of fair quality were made in small factories, at large profits which attracted so much competition that buyers bid up the price of offal to a high figure

With the perfecting of a direct heat drier in 1877, the packers began to enter the fertilizer industry, making the profits for themselves. Gradually other by-products were utilized, by the packers themselves, so that to-day practically every part of the animal is

used in some way in factories belonging to the large packing houses. In the small houses, slaughtering largely for intra-state or local trade, early conditions still obtain. Blood, offal, and even tankage frequently are discharged into the sewer in a way not tolerated in the large houses. To-day in the large houses, an attempt is made to save practically everything except the squeal, and even that the packers jokingly say is canned by a phonograph. In the pursuit of returns, grease is skimmed from the main sewer outfalls at Ashland and Center avenues and from the immediate surface of the river.

The endeavor of the industry, to secure economic recoveries has not, however, carried the efforts so far as to retain material of importance, not necessarily from the manufacturing standpoint, but from the standpoint of sewage disposal. There is still much material which passes away, in the aggregate thousands of tons a year, to which the practical manufacturer attaches little importance. To the sanitary engineer these wastes, containing large amounts of suspended matter with a liquid highly putrescible, are of great importance. For many years there has been a strong feeling that industrial waste of highly putrescible character is concentrated in the region along the South Fork of the Chicago River known as Bubbly Creek, yet no definite data had been found on which to base any recommendations for its treatment or use.

Many sanitary engineers of standing have felt that the legal minimum rate of flow prescribed for the Sanitary District by its charter was too low to care for the industrial load on the main channel in addition to the sewage of purely human origin. With the sluggish flow now existing in the West Arm and the moderate flow in the East Arm, it has been evident that sedimentation does occur both of organic and mineral suspended matter. The velocities of flow have not been made sufficiently high to scour. The condition of the South Fork has been vastly improved by the construction of the 39th street pumping station, and the use of the flushing pumps, but permanent improvement will not ensue until the quality of the waste discharged into the river is distinctly improved, and large amounts of suspended matter removed.

From time to time substantial deposits have been dredged out by the United States, the City of Chicago, the Sanitary District, and private corporations. The amount of material so removed amounts to several hundred thousand cubic yards, since the opening of the Drainage Canal in 1900. Banks of foul putrefying organic matter may still be seen at intervals along the South Fork, in particular along the West Arm, near Ashland avenue, where there

is a bank in the middle of a draw span. A record of soundings in the West Arm, west of Ashland avenue, shows that over a period of thirteen years, from 1895 to 1908, the shoaling has continued at a rate of 0.42 feet per year. In this dead end, fed solely by the Ashland avenue and Robey street sewers, and a little surface water from the original bed of the old West Arm east of Western avenue, the source of the deposits is at once evident. During the work preliminary to the opening of the conduit from the West Arm through Western avenue to the Drainage Canal, the Sanitary District removed approximately 100,000 cubic yards of material from the river west of Ashland avenue. Of this it is estimated that over 50 per cent. was typical sludge of sewage origin, in various stages of putrefaction.

PREVIOUS INVESTIGATION.

Early in the history of the Sanitary District, it was realized that something must be done to improve the condition of Bubbly Creek. In 1890 steps were taken by L. E. Cooley, then Chief Engineer, towards a comprehensive investigation covering gaugings of sewers and chemical analyses. Of this work only a few records are available, principally a table of analyses (Proceedings, 1891, p. 183) copied herein (table 1), and some plots of gagings. The analyses of the Stockyards sewage (Ashland avenue and Brennock sewers) made by Prof. J. H. Long agree very closely with the present day results.

At the same general period a report was made by W. E. Worthen, then Chief Engineer (Proceedings 1891, p. 140-4), in which the construction of an intercepting sewer or conduit was recommended of a capacity of 38 cubic feet per second from Halsted street westerly to receive all the Packingtown sewage. Flushing pumps were also proposed, the whole to discharge into the Illinois and Michigan Canal. Apparently, however, no attention was paid to the possible effect of this discharge on the canal.

Ten years later, in the report of the Sanitary Investigations of the Illinois River and its tributaries (Illinois State Board of Health, 1901), Prof. J. H. Long made a special report on the chemical and bacterial examination of the waters of the Illinois River and its principal tributaries (pp. 66-67). Comment was made on the conditions existing in Bubbly Creek and the North Branch as follows:

> "An extremely important factor in determining the character of the Bridgeport discharge is the drainage from the stockyards sewers, and in former years the output of these was much greater in amount of organic matter than at the present time. In 1886 I made some examinations of the flow of the main sewer, and found that the organic matter discharged by it when calcu-

lated to the dry condition amounted to over 112 tons daily, which is about equivalent to the closet sewage of a population of 1,350,000. This large content was exceeded greatly in earlier years when the commercial value of the waste was not appreciated. Several years later, in 1890 and 1891, I had occasion to make extended investigations of the character of the sewage reaching Bridgeport from several quarters. Over twenty complete tests were made on the sewage discharged from the Brennock and Ashland sewers combined, the samples being collected in such a manner as to secure a very accurate and fair average for the flow of the 24 hours. With a mean discharge of 1,336,000 cubic feet per day, the organic matter present was 2,428 parts per million, corresponding to 91,850 kilograms or about 101 tons daily. At the same period the discharge of the Halsted and 39th street sewers was 9.3 tons of dry, organic matter. The total nitrogen from the Ashland and Brennock sewers, counted as ammonia, was 418.5 parts per million, amounting to 15,820 kilograms, or 17.4 tons daily. From the Halsted and 39th street sewers the amount was 37.2 parts per million, corresponding to 1,406 kilograms daily, or 1.25 tons. For the two sewer systems the ratio of ammonia to total organic solids is nearly the same, and high enough to indicate the essential proteid character of the waste.

"I believe these results may be applied to present conditions (1901) with a fair degree of accuracy. While many improvements have been made in processes for utilizing stockyards waste, the gain is practically compensated for by the increased slaughtering of cattle and hogs. Extensions in the Ashland avenue and Halsted street sewer systems bring also a greatly increased amount of sewage from points south of the stockyards, so that the final discharge must now be above the figures given. Approximately, then, the flow at Bridgeport can be taken as made up of city sewage containing 150 tons daily of dry organic matter and the combined stockyards and Ashland and Halsted sewers, containing about 110 tons daily, but from the latter must be deducted the fraction of house sewage it contains, which in dry organic matter must amount to about 20 tons, as the contributing district has a population of about 200,000. Supposing the above assumption as to the constant flow from the stockyards correct, we must add 90 tons of dry organic matter to that from the city flowing toward the Bridgeport pumps."

The Board of Health of the City of Chicago has from time to time made cursory examinations of the slaughter houses from the standpoint of sanitary conditions (cf. Reports Dept. Public Health, Chicago, 1904-1910). Attention was principally directed to reducing the odors, the larger volume of which arise from the fertilizer driers. The nuisance from Packingtown to-day is largely aerial. The odor is unmistakable, and travels miles under favorable atmospheric conditions.

RESULTS OBTAINED.

Notwithstanding all these investigations, little has been done from the standpoint of improving the condition of Bubbly Creek by the treatment of the pollution. The object of our investigation was to establish definitely the probable amounts of waste to be expected and suggest the ways and means of handling the problem with a view to immediate action.

PRESENT INVESTIGATION.

An extended investigation was begun early in January, 1911, to cover all the industrial wastes which enter the Drainage Canal. Lists of probable sources of wastes were prepared, and as time has permitted, the localities have been examined, and samples collected. So far, the detailed investigation has been confined to the stockyards region and its immediate vicinity.

Conditions along the Chicago River have changed so markedly in the last twenty years, that industrial practices which once passed unnoticed are fast becoming a serious problem. Again, with the occupation of the water-front, adjacent properties are sometimes directly injured by deposits from a neighboring factory up-stream. Hence the growth of the city and the accompanying congestion have brought about changed conditions, which must be faced in order to avoid conditions worse than the present.

PURPOSE.

The purpose is not to drive manufacturers or industries away, but to secure such co-operation as will gradually improve existing conditions in an economical and scientific way. Treatment of industrial wastes is vitally necessary to prevent the canal from becoming a dumping ground for all kinds of industrial refuse, and thereby increasing the load on the canal itself.

IMPROVEMENTS.

However, it is frequently impossible at first to suggest off-hand the necessary improvements in detail, as none of the houses examined so far had exact knowledge of the flow or quality of their discharges prior to examination by us. Measurements and tests are necessary, sometimes over an extended period. Plants vary, as well as operating conditions. Continued co-operation, study, and improvement are therefore necessary. In addition to the work already

TABLE 1.

MEANS OF ANALYSES OF SEWAGE SAMPLES.

(BY PROF. J. H. LONG.)

RESULTS GIVEN IN PARTS PER MILLION.

	Halsted and 39th St. Nov. 5–25, 1890.	Halsted and 39th St. Storm Water, Nov. 16, 1890.	Ashland Ave. and Brennock sewers, Dec. 5–30, incl., 1890.	I. & M. Canal at Bridgeport, Oct. 16, to Dec. 30, 1890.	Main St., So. Branch, Dec. 26–29, 1890.	39th St. and So. Fork, Nov. 29, 1890.	22nd St. and So. Branch, Nov. 29, 1890.	Polk St. Bridge, So. Branch, Nov. 28, 1890.	Madison St. Bridge, So. Branch, Nov. 28, 1890.	Kinzis St. Br dge, N. Br., Nov. 27, '90.	Goose Isl., No. Br. Nov. 27, 1890.	Fullerton Av. Bdg., Nov. 26, 1890.	Clybourn Pl., Nov. 26, 1890.
Number of Samples	21	1	24	76	3	1	1	1	1	1	1	1	1
Temp. of Samples (Centigrade)	10.04	......	17.7	8.6	......	......	......	......	......	......	......	......	......
Total Solids in Whole	973.0	782	6475.7	493.2	320.7	2394	398	360	272	342	294	216	226
Fixed Solids in Whole	694.9	588	4048.0	391.7	236.0	2092	344	286	226	276	226	188	190
Volatile and Organic	278.1	194	2427.7	101.5	84.7	302	54	74	46	66	68	28	36
Total Solids in Solution	815.4	674	5581.3	388.2	287.3	2258	236	268	216	254	244	174	216
Fixed Solids in Solution	628.6	566	3860.3	320.5	218.7	2008	200	214	170	198	206	146	186
Volatile and Organic	186.8	108	1721.0	67.7	68.6	250	36	54	46	56	38	28	30
Solids in Suspension	157.6	108	894.4	105.0	33.3	136	162	92	56	88	50	42	10
Total Nitrogen (Kjelhdahl)	30.6	42.0	327.4	18.01	11.39	157.92	6.44	7.56	5.04	6.16	5.04	2.52	3.64
Total Nitrogen as Ammonia	37.2	51.0	418.5	21.85	13.83	191.76	7.82	9.18	6.12	7.48	6.12	3.06	4.42
Free Ammonia in Filtrate	14.6	20.8	81.7	13.17	5.68	152.00	2.56	2.88	2.94	2.40	1.92	1.44	2.18
Albuminoid Ammonia, in Filtrate	5.0	2.1	112.7	1.65	2.59	6.20	0.96	1.28	1.10	1.68	1.04	0.67	1.56
Oxygen Consumed in Filtrate	72.6	38.7	428.8	20.60	14.85	70.40	11.52	11.12	7.68	10.88	11.52	2.24	2.72
Chlorine in Filtrate	108.0	116.1	1894.8	70.33	25.25	916.15	16.28	18.01	14.51	18.40	14.33	5.66	8.67

From proceedings, Board of Trustees, the Sanitary District of Chicago, 1891, p. 183.

accomplished in the Stockyards district, typical plants should be selected in the other industries, best adapted for experiment and devices should be installed to enable the study on a working scale not only of the sedimentation problem, which is usually essential, but also of further treatment, in order to be prepared for the future, when the reduction of the load of dissolved putrescible matter arising from trade wastes may be needed.

PACKERS' COMMITTEE.

In 1911, as a result of preliminary work carried on by the District, the various firms operating in Packingtown and the Union Stockyards and Transit Co. were called in for conferences to help relieve the situation by preventing deposits. As a result a committee was appointed to act for the various firms, a fund being contributed, amounting to $26,864.38, to dredge out deposits in the east and west arms of the south fork of the Chicago River. This work, postponed from time to time, was finally completed in 1913. Later, in 1912, a fund of $2,600 was contributed by the firms toward defraying the cost of a testing station at the outlet of Center avenue sewer, the balance of the cost to be paid by the Sanitary District. In 1912 a joint committee of three members each of the Health committee of the City Council of the City of Chicago, the packers and the trustees of the Sanitary District, inspected sewage treatment plants in the East. To date, hearty co-operation has been secured from all the firms in the Stockyards and Packingtown.

STOCKYARDS AND PACKINGTOWN.

One of the largest industries in Chicago, if not the largest, is the animal industry centered in and around an area about a mile square, comprising the Stockyards and Packingtown. A great variety of processes is carried on, from the handling of live stock to the final disposition of the meat products and by-products, in many different ways. Investigations show the following industries:

Stockyards, including the handling and storage of live stock of all kinds.

Packers, including slaughtering and packing, as well as the making of by-products, in greater or lesser degree.

Butterine works.

Rendering establishments.

Soap factories.

Glue factories.

Casing makers.

Sausage makers.

Garbage rendering (The Chicago Reduction Co., up to 1914, when purchased by the city).

Canning of fruits, vegetables, and meats.

Pickle manufacturers.

Breweries.

FIRMS. The list of firms engaged in these industries is given in Appendix I.

MAGNITUDE OF PROBLEM. In order to show the magnitude of the problem, figures furnished by the Drovers' Journal have been compiled, giving the statistics of the head of cattle, hogs, sheep and calves used in the city. This represents very closely the total head slaughtered. The figures extend from the beginning of the stock-yards, in 1866, to date, and are shown in table 2. In Fig. 1 is plotted the total head slaughtered each year, as well as the total popu-

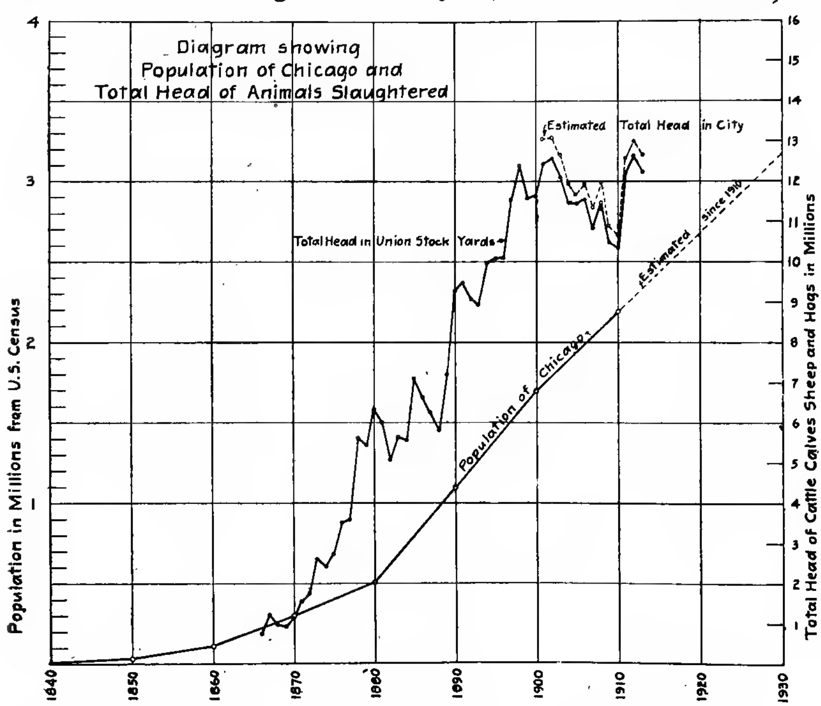


Fig. 1.

lation of the City of Chicago, as given by the U. S. census. The curves show a decrease in business done in Packingtown since 1900, probably due to the increasing number of other Western packing centers, at Kansas City, St. Joseph, Omaha, Fort Worth, etc. Since the development of the industry has been accompanied by marked

TABLE 2.

RECORD OF ANIMALS LEFT IN CHICAGO AND PRESUMABLY SLAUGHTERED. 1866 TO 1913.

Compiled from Statistics Furnished by the Drovers' Journal.

Year	Cattle	Calves	Hogs	Sheep	Total Head
1866	129,314	....	478,871	132,540	740,725
7	125,608	....	937,949	130,613	1,201,170
8	108,537	....	686,453	189,257	984,247
9	108,385	....	575,564	231,382	915,331
1870	141,255	....	768,705	233,141	1,143,101
1	141,132	....	1,218,697	179,969	1,539,796
2	174,050	....	1,417,029	165,195	1,756,274
3	187,247	....	2,240,193	176,499	2,603,939
4	221,037	....	2,028,018	148,100	2,397,155
5	224,309	....	2,329,467	175,344	2,729,120
6	299,021	....	3,058,371	168,170	3,525,562
7	329,749	....	3,074,749	154,886	3,559,384
8	393,960	....	5,072,748	153,693	5,620,401
9	488,629	....	4,755,969	165,853	5,410,451
1880	495,863	....	5,664,565	179,300	6,339,728
1	559,837	15,483	5,185,165	239,686	6,000,171
2	661,521	14,636	4,069,782	314,687	5,060,626
3	912,186	17,552	4,321,233	375,454	5,626,425
4	1,025,813	21,264	3,959,352	511,275	5,517,704
5	1,161,524	24,890	5,140,089	743,321	7,069,725
6	1,259,225	32,633	4,627,977	741,878	6,661,713
7	1,590,525	49,903	3,658,851	915,768	6,215,047
8	1,643,158	72,423	3,169,883	913,773	5,799,237
9	1,763,310	87,392	4,211,867	1,121,154	7,183,723
1890	2,223,971	113,559	5,678,129	1,256,813	9,272,472
1	2,184,095	157,052	5,638,291	1,465,332	9,444,770
2	2,450,121	166,572	4,788,290	1,661,711	9,066,694
3	2,233,243	196,725	3,908,318	2,588,309	8,926,595
4	2,023,625	149,061	5,018,170	2,766,327	9,957,183
5	1,803,466	158,858	5,784,670	2,932,093	10,679,087
6	1,782,150	131,880	5,763,160	3,029,416	10,706,606
7	1,711,532	111,759	6,733,740	2,968,530	11,525,561
8	1,615,255	104,889	7,476,570	3,046,014	12,242,728
9	1,702,572	118,489	6,488,431	3,295,841	11,605,333
1900	1,794,397	122,250	6,656,881	3,061,631	11,635,159
1	1,999,820	162,437	6,989,532	3,280,793	12,432,582
2	2,031,644	224,977	6,643,440	3,683,988	12,584,049
3	2,163,031	245,499	6,088,369	3,582,651	12,079,550
4	2,922,853	244,083	5,612,724	3,142,360	11,922,020
5	2,010,256	354,008	5,697,632	3,380,693	11,442,589
6	2,176,252	389,944	5,533,457	3,464,176	11,563,829
7	1,853,240	397,097	5,490,159	3,069,391	10,809,887
8	1,683,870	390,322	6,261,707	3,137,817	11,473,723
9	1,662,126	380,138	4,955,025	3,501,103	10,498,392
1910	1,741,074	464,742	4,384,468	3,735,346	10,325,630
11	1,715,279	493,561	5,576,638	4,452,810	12,238,288
12	1,681,136	482,932	5,608,415	4,880,873	12,653,356
13	1,530,625	356,921	5,898,292	4,453,610	12,239,448

improvement in the saving of wastes and their utilization in by-products, particularly among the large houses, it is probable that the increase in pollution due to the increase in the industry has not

been in a direct ratio to the increase in the head slaughtered. The small houses, however, still discharge a large proportion of their wastes, including much valuable material, which should be taken care of. The scale on which their operations are conducted, however, does not permit the economies of the larger houses.

SEASONAL DISTRIBUTION. From the standpoint of the operation of the canal, and the load of organic matter to be cared for, it is important that the seasonal distribution be known. The

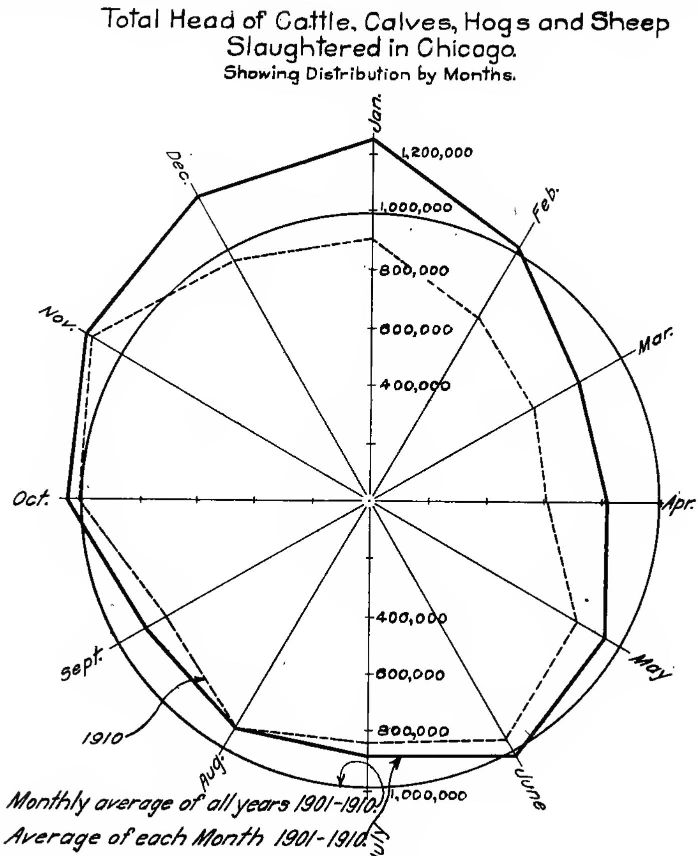


Fig. 2. Seasonal Distribution of Killing.

total head slaughtered has been averaged by months for the past ten years, and plotted in Fig. 2. This shows a slightly heavier load in the autumn and early winter than in the spring and summer months.

PRELIMINARY TESTS. In order to determine the condition existing in Packingtown, an inspection was made of the various

catch basins or outlets of the houses. Some catch basins are provided with screens, others are not. Existing screens are often as large as 1 inch mesh, and in general are of little use. The catch basins are built primarily to act as skimming basins for grease and are too small, as a rule, to catch much, if any, of the settling suspended matter, or even all the grease. Where material does settle, it has not always been removed. In some cases, the basins are flushed into the sewers or river, either automatically by siphons or by hand, or by the slow unloading caused by violent septic action. The large houses save more material than the small. The common source of trouble seems to be the paunch manure of cattle, though various particles of organic matter also appear.

The general practice has been to build catch basins on those sewers which will yield some return in grease or fertilizer. The paunch manure and other waste lines are frequently by-passed around the catch basins, no treatment being provided. There are of course exceptions where care is taken to handle everything, even though but roughly. Where hogs are slaughtered, the paunch manure is usually saved for use as fertilizer. The cattle paunch manure has no value as such.

The preliminary tests were made by collecting a portion of the liquid every ten minutes, for a period of one hour, and mixing the portions thus collected into an average sample. The results are shown in table 3. Comparison with the normal city sewage shows from 4 to 60 times the content of suspended matter, based on the total. If the proportion of volatile matter be considered in most cases the ratio would be from 5 to 100 times the amount of suspended organic matter, susceptible to putrefaction.

The "Oxygen Consumed" test indicates roughly the amount of carbonaceous matter present requiring oxidization. Part is dissolved, part suspended. From 5 to 70 times as much "oxygen consumed" is found in these industrial wastes as in the average normal city sewage.

The "Organic Nitrogen" test furnishes an index to the amount of putrefaction which may be expected if sufficient fresh water is lacking to cover the needs of the nitrogeneous decomposition products. From 4 to 140 times as much organic nitrogen is found in the industrial wastes as in the 39th street sewage.

THE PACKING INDUSTRY.

PROCESSES INVOLVED. A brief summary is here given of the various processes involved in a modern packing house, and the waste products which may accrue. The information is obtained

TABLE 3.

RESULTS OF PRELIMINARY ANALYSES, PACKINGTOWN INVESTIGATIONS.

RESULTS IN PARTS PER MILLION.

DATE 1911	NITROGEN AS		Oxygen Consumed	Chlorine	SUSPENDED MATTER			Alka-linity	Fats	REMARKS
	Total Organic	Free Ammonia			Total	Volatile	Fixed			
					ANGLO-AMERICAN PROVISION CO.					
Jan. 26	84	20	2738	654	8948	8628	320	136	3840	Red. Brown
					WESTERN PACKING AND PROVISION CO.					
Jan. 30	51	13	227	671	712	600	112	252	....	Red. Brown
					G. H. HAMMOND CO.					
Jan. 31	66	....	626	3538	1536	1296	240	368	....	Red Brown
Feb. 20	351	8.8	974	576	2880	2584	296	440	....	Gray. Brown. Heavy Sediment
					ARMOUR AND CO.					
Jan. 31	36	....	263	2458	524	392	132	120	....	Gray
					BOYD, LUNHAM AND CO.					
Feb. 15	130	....	484	730	840	676	164	312	....	Red
					MORRIS AND CO.					
Feb. 16	123	....	424	1576	692	600	92	304	....	Gray
Mar. 2	296	....	628	1244	1044	912	132	284	249	Red. Brown. Hog House
					SULZBERGER AND SONS.					
Feb. 20	268	5.8	224	1728	752	676	76	212	....	Yellowish Turbid
Feb. 20	171	6.6	428	3234	2080	1920	160	240	....	Reddish
					HENRY GUTH.					
Feb. 23	530	138	1025	2746	1132	928	204	1140	....	Red. Brown
					INDEPENDENT PACKING CO.					
Feb. 23	374	26	800	974	536	496	40	244	....	Brownish Yellow
					LOUIS PFAELZER AND SONS.					
Mar. 2	1075	435	1920	2553	2760	2640	120	1700	759	Red turning to green Odor of putrid bile
					HINE BROS. CO.					
Mar. 7	780	80	2452	843	2440	2408	32	420	....	Coffee Brown. Heavy Sediment

TABLE 3—Continued.

RESULTS OF PRELIMINARY ANALYSES, PACKINGTOWN INVESTIGATIONS.

RESULTS IN PARTS PER MILLION

DATE 1911	NITROGEN AS		Oxygen Consumed	Chlorine	SUSPENDED MATTER			Alkalinity	Fats	REMARKS.
	Total Organic	Free Ammonia			Total	Volatile	Fixed			
					L. GLICK.					
Feb. 8	733	80	1648	1874	4876	3804	1072	728	....	Milky Yellow. White Sediment
					SWIFT AND CO.					
Feb. 16	103	....	416	1564	1376	1220	156	140	....	Gray. CB. V.
Mar. 7	70	56	479	3623	444	336	108	290	....	Black. Dye House
					FRIEDMAN MFG. CO.					
Mar. 7	289	11	1056	2368	2732	2712	20	330	....	Milky White
					BRENNAN PACKING CO.					
Mar. 1	1134	66	1956	943	3784	3100	684	460	....	Reddish Brown*
	1067	53	1876	893	3220	2916	304	390	3477	Red Brown. Manhole
Mar. 16	365	35	....	7228	1104	840	264	460	209	Brown. Last M. H.
	498	40	....	5908	2820	2068	752	390	611	Brown*
					UNION STOCK YARDS AND TRANSIT CO.					
Feb. 15	185	....	1206	68	4420	3484	936	640	....	Gray Sediment
					ADLER AND OBERNDORF.					
Apr. 19	358	42	692	1188	760	720	40	230	....	Yellow Turbid. Heavy Sediment
					CHICAGO PACKING CO.					
Apr. 19	280	40	668	4163	1220	1120	100	400	....	Red. Turbid. Heavy Sediment
					MILLER AND HART.					
Apr. 19	607	433	2096	2508	8520	7640	880	1400	....	Yellow Turbid. Heavy Sediment
					STANDARD SLAUGHTERING CO.					
Apr. 19	1005	115	1572	118	3620	3440	180	720	....	Yellow. Heavy Sediment

(*) Catch Basin under platform.

in part from "The Modern Packing House," by F. W. Wilder, from the "History of the Union Stockyards," by W. Jos. Grand, and largely from conversations with various superintendents and officials in Packingtown. The subdivision of the industry is carried out *in toto* by most of the larger houses. The smaller houses curtail in accordance with their size. The operations vary with the kill, whether of cattle, hogs or sheep. Edible and inedible products are sharply distinguished. Material from catch-basins is classed as inedible, particularly where human sewage has entered.

CATTLE PACKING.

KILLING. In the killing room the cattle are slaughtered, the beef going to the coolers. The hides are piled on trucks and run to the cellar. The offal is collected from the killing floor and distributed as follows:

1. Blood to fertilizer house.
2. Fats to oil house.
3. Casings cleaned and packed. The smaller houses sell their casings to several specialty men.
4. The tripe is cleaned and sent to the tripe room.
5. Livers, tongues, hearts, etc., are trimmed and sent to the cooler.
6. Heads and feet to the bone house.
7. The paunch manure is gathered up and pressed. At one time many houses burned it in their furnaces. Now it is shipped away and sold for manure. Some escapes in the sewers.
8. Miscellaneous scraps to the tank house.

HIDE CELLAR. The hides are cured with salt in piles or packs in a cellar. These are kept as tight as possible to avoid shrinkage. Before packing the loose ends are trimmed off, and sent to the glue factory.

OIL HOUSE. The tallow is rendered in tanks under 40 lbs. steam pressure. If high colored it is inedible, hence this is kept as small in amount as possible. "Oleo" is made by macerating the fats, then cooking at moderate heat to release all the oils without burning the tissue. The oil is allowed to settle, the vat is salted, then the oil is decanted into a clarifier and skimmed. Finally the oil is withdrawn into seeding trucks or vats, and after standing a short period is pressed through cloths. The finished product is the oleo, which is run into receiving tanks, and the stearine, which remains in the filter cloths being used in compound lard. There is usually a scrap vat in the oil house, which is skimmed, the balance of the solid mat-

ter being sent to the tank house. The "oleo" is used in making oleomargarine.

BUTTERINE HOUSE. Butterine, or oleomargarine, is made from the oleo or fat, mixed with milk or cream. The mixture is sterilized, then seeded with a butter culture of selected bacteria, and ripened into butterine.

TANK HOUSE. The tank house is equipped with a number of digesters in which all the offal from the various houses is cooked at 40 lbs. steam pressure to disintegrate the organic matter and liberate the grease. The residue is pressed and dried, being sold as "tankage" for fertilizer. The tank water is condensed steam from the cooking, and is rich in the sediments and juices of the material worked over. It is evaporated into "stick." The press water is also evaporated. If these liquids are stored for any length of time, steam coils are used to keep them hot and sweet, as well as to promote the separation of the fat.

Concentrated tankage, as sold, is made from the stick, mixed with blood, a small amount of crude sulphuric acid, and a chemical, so-called, containing iron sulphate and manganese. The mixture is dried in ovens or on a steam heated roller, broken and ground. Sometimes the tank waters are stored in vats at 180 degrees Fahr. for 24 hours. The grease is skimmed, then copperas is added. After a second skimming the liquor is evaporated, the stick is mixed with tankage (picked to pieces) and the mass dried.

CASINGS. Casings consist of the round or small guts, middle or large intestines, bungs, weasands, and bladders. They are saved from cattle, hogs and sheep. After washing in clear water, they are cleaned of their contents by hand or machine, and measured into sets. They are then salted and drained for a day, and, after being resalted, are packed in barrels for shipment. They should be kept moist. The offal from the removal of fat and pieces of membrane, as well as the cleanings, can be rendered to extract the grease. The wash waters contain a deal of suspended matter.

FERTILIZER. The various materials which are sold as fertilizer may be treated in the fertilizer house, before final shipment.

1. The blood from the killing floors is coagulated in vats by cooking. The water is drained off, the residue pressed and dried. The cake may be ground and screened. The blood and concentrated tankage are high in ammonia.

2. Ordinary tankage. This is the residue from the cooking and pressing of the finished products. The cakes are picked to pieces

or broken up by machine, then dried, and sometimes ground and screened.

3. Bone meal, or ground steam bone, are covered by the term "bone phosphate."

TRIPE ROOM. The "tripe" is the muscular part of the stomach of the cattle. In the preparation the stomachs are emptied of their contents, washed, scalded, scraped and boiled till tender. They are then cooled, and the fatty layers scraped off, leaving behind the "tripe" proper. This is pickled in vinegar. Wash water and the cooking water come from this process.

SAUSAGE ROOM. Some of the blood is used for blood sausage, a part for coloring head-cheese. Livers are made into liver sausage.

BONE DEPARTMENT. To this house all the horns, skulls, jaws, bones, etc., are sent. Two products can be made:

1. Hard bone. In this case the bones are cooked, at a low temperature.

2. Steam bone. The bones here are cooked with steam in digesters to extract the glue. Neatsfoot oil may be extracted from the hoofs. The sinews can be turned into glue stock, by curing with salt. Wash waters result from the vats.

The tips of the horns are made into bone ware, combs and other articles. Shank bones are used for knife handles in cheap grades of cutlery. Ankle and knee bones are thoroughly de-greased and shipped abroad for use in sugar refining. Tails are largely used in making ox-tail soup.

SHEEP PACKING.

The slaughtering of the sheep, and the other processes follow very closely after the cattle scheme. It is usually carried on by firms which handle cattle and hogs as well, so that the wastes are treated in the same way.

HOG PACKING.

On the hog killing floor, the hogs are slaughtered. The carcass is then scalded, scraped and shaved to remove the hair. After the guts and leaf lard are removed, the hog is split and sent to the chilling room. The grades and sizes are carefully assorted.

CUTTING AND GRADING. Part of the hog is carefully trimmed and cut up for sale as fresh meat, the rest is pickled, dry salted, or pickled and smoked.

SAUSAGE ROOM. Various kinds of sausage are made from the pork. The fillings are packed into the casings from the casing room.

In a small factory, making sausage, there is much small offal which reaches the sewers.

LARD, GREASE, ETC. The lard is refined from the leaf lard taken from the killing room.

The grease collected from the various skimming basins is largely inedible. Oil is pressed out of the skimmings. The low grade fats are first washed with sulphuric acid to eliminate the impurities.

HOG HAIR. Hog hair is either (1) sun dried out doors, or (2) cooked in large vats, run through wringers and dried by artificial heat. In some cases the hair is dyed. It is then baled up and sold to mattress manufacturers, etc. Practically no bristles are grown in this country.

MISCELLANEOUS.

ALLIED INDUSTRIES. There are several allied industries which may or may not be directly under the same roof as the packing house, and its immediate adjuncts. Under this head are listed the canning department, the soap works, glue factory, ammonia works, cooperage, car shops, power house and pickle factory.

CANNING DEPARTMENT. Here all kinds of meats are canned by cooking and sealing in air-tight containers. Various fancy mixtures are made. Soups are also mixed. Some packers add vegetables to the soups, as a filler. Others put up pickles as well.

SOAP WORKS. In the soap works most of the inedible fat or oil is worked up into soap.

GLUE AND AMMONIA WORKS. This industry is so diverse and so prolific of liquid wastes, as well as solid, that it is treated separately.

BUTTON MANUFACTURE. From the horns and bones buttons are made. These may be dyed.

COOPERAGE, CAR SHOPS AND POWER HOUSE. From the cooperage and car shops only human excreta originates, as a rule. The power house, in some cases, is very large, using several million gallons of condenser water daily. In some plants a large portion of the condenser water is drawn from the catch basins. In other plants the condenser water is pumped back into the catch basin. This may, and does, create scouring velocities, washing much material through that should normally settle.

PHARMACEUTICAL PREPARATIONS. From certain special parts various pharmaceutical preparations are prepared, as, for instance, the bile is used for pharmacopaeal ox-gall. Pepsin, pancreatin, and other material is made.

MANUFACTURE OF GLUE.

The following statement of the processes in the manufacture of glue is compiled from articles in the Encyclopaedia Brittanica, 11th Edition, and from Thorp's Outline of Industrial Chemistry. The processes described therein have been checked by conversations with the manufacturers in Chicago. Commercial glue can be made from hides, bones or fish. In Chicago hide and bone glue are the two varieties made.

Hide glue is made by extracting the gelatinous material from the waste bits of hide, trimmings, fleshings and other untainted untanned refuse from the tanneries, or slaughter house waste, such as the ear-laps, hides, sinews, feet and tails of cattle and sheep. The raw material, whether wet, or dried and salted, is washed and steeped in vats from 2 to 10 weeks with lime water. The lime removes all blood and flesh, forming a lime soap with the fatty matter present. The stock is then thoroughly washed in tubs with mechanical stirrers or rollers which remove the lime, lime-soap and dirt. The last traces of lime are removed by treating with dilute sulphurous acid. The excess acid is washed away. The stock is then ready for cooking. The kettles are open boilers with a false bottom. The cooking is continued to a point where a test simply cools to a stiff jelly. The grease and lime soaps rise to the surface and are skimmed off. The solid matter, consisting of hair, etc., sinks and forms a filter at the bottom of the tank, with excelsior placed there, through which the liquid is slowly drawn off through the false bottom, and a clear solution obtained. The final concentration of the liquor is accomplished in evaporating pans with several effects. The glue is passed into sheet iron molds, cooled, cut with wire knives and run through drying chambers.

The principal waste from these processes is the solid matter, largely lime-soap, which is discharged from the liming vats and in the wash water from the stirrers. Scraps, hair and other particles of offal work their way through with the sediment.

BONE GLUE. Bone glue is made from bones, which may be supplied fresh, or after use in making soups. Fresh bones contain about 50 per cent. mineral matter, mainly calcium and magnesium phosphates, which may appear later as fertilizer and bone-meal, about 12 per cent. each of moisture and fat, the fat being utilized in the manufacture of soap and glycerine, the remaining material being the other organic matter which supplies the glue.

The degreasing of the bones may be effected, first, by boiling with water in open vessels and skimming off the grease as it rises,

or, secondly, by treatment with steam under pressure, or, thirdly, by means of a solvent, such as benzine or petroleum. The de-greased bones are cleaned by attrition, producing a little meal. The bones now contain 5 or 6 per cent. of glue-forming nitrogen and about 60 per cent. calcium phosphate. They are steamed in upright digesters under pressure until all the glue stock is dissolved. The glue liquor is then run off and clarified, and concentrated by vacuum pans, or in open troughs with a rotary steam coil half submerged in the liquid. The concentrated liquor may be bleached by sulphurous acid. It is then jellied and cut into sheets for drying.

WASTE. There would seem to be much less waste material in the manufacture of bone glue than for the hide glue, since lime is not used. The waste appears to be principally wash water, and the condenser water from the vacuum pans, with scraps and a small amount of grease. In the making of hide glue, particularly where liming tanks are used, much lime soap may be wasted, as well as the wash water from the stirrers, hair particles, etc.

BY-PRODUCTS. In some glue houses not only is glue manufactured, but considerable amounts of fertilizer, tallow, and grease are made. The fertilizer may come from the bone meal, the tankage from the rendering tanks, the scraps of leather often collected from the tanneries, the solid refuse from the catch basins of the bone glue houses, etc. Tallow and grease are made, the tallow from the suet, the grease from the skimming of the catch basins and the extraction from the rendering tanks as well as in the process of glue making. In some cases, the residue is collected from butchers who try out tallow. This is rendered, the final residue being pressed into cake, and sold for chicken feed.

CHAPTER II.

EXAMINATION OF INDIVIDUAL HOUSES.

GENERAL. Following the preliminary tests made early in 1911, an extended investigation was planned covering every individual main sewer in Packingtown, to determine the actual flow and the variation in amount and quality through the twenty-four hours of the day.

CO-OPERATION OF UNION STOCKYARDS AND PACKERS. When the object of the investigation was explained, the head officials of the Union Stockyards and the various packing companies

offered to co-operate by furnishing detailed maps of their sewers and catch basins. They also supplied in nearly every case carpenters and laborers to install weirs at the points selected, and the material, as well as the lights for use at night. From the data obtained, the sewer map of the Yards and Packingtown has been compiled (Fig. 3). This shows all the main outlets and catch basins, as well as the municipal sewers. In this territory nearly a mile square, none of the streets have been dedicated. Sewers have been built in every conceivable direction, without plan, each house running sewers as it saw fit. Consequently an under-ground network of pipes has arisen of which the records are faulty, although our compilation represents the best obtainable data. The city sewer, known as the Center avenue sewer, is built under easements. The condition of all sewers is commented on elsewhere.

PACKING HOUSES.

CLASSIFICATION. These may be divided into three heads:

1. The large slaughtering establishments represented by Armour & Co., Swift & Co., and the like, with their allied factories for using all the by-products. 2. The small establishments which slaughter and make a few by-products. 3. The smallest places which merely slaughter.

LARGE SLAUGHTER HOUSES. In the large factories, the basic operations to which possible waste may be traced may be divided as follows:

1. Slaughtering of steers, sheep or hogs:
   a. Contents of intestines, or paunch manure.
   b. Wash water, containing:
      1. Blood,
      2. Manure,
      3. Particles of hair, flesh, etc.
2. Packing, covering all the processes of preparing edible products.
3. Rendering.
4. Hides, liming or salting, and drainage from hide cellar.
5. Hair; the removal, washing and dying.
6. Glue manufacture.
7. Wash and cleansing waters in general from floors, yards, pens, etc.

SMALL SLAUGHTER HOUSES. In the small factories the wastes may come from:

1. Slaughtering.
2. Packing.
3. Rendering.

TABLE 5.

RECORD OF KILLING OF HOGS FROM 1906 TO 1913 IN CHICAGO.

Compiled from Statistics Furnished by Drovers Journal.

House	1906	1907	1908	1909	1910	1911	1912	1913
Armour & Co.	1,498,000	1,335,000	1,613,500	1,224,200	1,118,900	1,373,000	1,340,900	1,325,900
Swift & Co.	1,080,900	1,001,000	1,100,000	855,500	770,900	959,000	1,060,800	928,700
Sulzberger Sons Co.	523,400	549,000	788,600	570,200	521,800	676,000	682,000	607,500
Morris & Co.	418,600	440,000	524,400	427,700	350,400	416,000	430,900	482,500
Anglo-American	463,000	367,000	410,000	304,800	225,600	274,000	273,800	317,800
Boyd, Lunham & Co.	316,100	353,000	317,800	221,100	160,200	268,800	236,900	280,000
Hammond	266,500	287,000	393,200	387,300	315,500	334,800	345,200	405,900
Continental Packing	198,900	163,000	......	......	......	......	......	......
Boore & Co.	198,500	225,000	206,000	178,300	78,900	......	......	......
Roberts & Oakes	184,200	197,000	203,400	143,200	142,600	184,400	130,800	223,600
Western Packing Co.	115,400	268,000	381,400	267,000	236,800	330,500	311,000	394,400
Others (incl. down-town)	793,500	805,000	843,100	789,200	683,700	967,600	1,034,600	1,164,800
TOTAL	6,057,000	5,990,000	6,781,000	5,368,000	4,605,300	5,785,800	5,855,900	6,131,100
Down-town (included in total)	524,387	515,078	519,498	415,878	339,154	352,845	390,769	396,801

The wastes here are usually stronger. Blood is frequently lost in quantity, if not altogether, as well as pieces of entrail, contents of stomachs, etc. Some of the smallest houses do not even have rendering tanks.

MANUFACTURING. The general processes carried on by the various houses are essentially the same, as a rule, for the larger houses, a brief summary being given in Chapter 1. Since the details vary somewhat, house by house, a compilation of the various steps has been made. Table 4 shows what each house normally is doing. Hence the sewage discharged by each house can be scrutinized more readily. Table 5 gives the yearly kill of hogs for the larger companies, compiled from statistics furnished by the Drovers' Journal.

FLOW. An attempt was made to measure the flow from each house at the time of the collection of the chemical samples. Whenever possible, this was extended over 24 hours or more, to learn the variation in composition and the amount of the night and day sewage. The smaller houses usually shut down at night, since all their operations can be completed in the day time, when the slaughtering is carried on. The larger houses frequently run a portion of their plant all night, and at times the entire plant. During the period of our test, the killing was light. Some night work was carried on. The night flow, however, from most of the larger houses was about half the day rate (table 6).

COLLECTION OF SAMPLES. The samples were collected in small portions every 10, 15 or 20 minutes, according to circumstances, and then averaged into 1 or 2 or 4 hour collections. In some cases the individual averages were analyzed. In others the hourly collections were averaged for 4 to 12 hours in accordance with the flow, and the final average analyzed. The averaging was governed by the appearance of the sample and the flow, the effort being to cover as much ground as possible with each analysis, as well as to distinguish the peaks.

ANALYSIS. From our present standpoint, the content of suspended matter was the most important, since it indicates the amount of material which can be removed more or less completely by settling. Both the volatile and fixed or mineral matter were determined. Whenever time permitted, the oxygen consumed, organic nitrogen, and other standard determinations were made on composite samples covering typical periods, to compare the character of the discharges with city sewage. Whenever a sample showed any floating fat, the fats were determined.

RESULTS OF ANALYSIS. The results of the analyses in

TABLE 6.

SUMMARY OF FLOWS AND DISCHARGE OF SUSPENDED MATTER FROM PACKING HOUSES IN AND AROUND PACKINGTOWN.

1911.

FIRM	8 A. M. to 8 P. M.		8 P. M. to 8 A. M.		Total Susp. Mat.		Remarks.
	Flow c. f. s.	Susp. Mat. p. p. m.	Flow c. f. s.	Susp. Mat. p. p. m.	Day lbs. dry.	Night lbs. dry.	
Adler & Oberndorf	0.14	432	....	....	163	....	
Anglo-American							
Catch Basin (A)	1.62	322	1.15	156	1408	484	
Total (B)	1.98	210	1.17	103	1120	325	
Armour & Co							
43d St. (A)	2.98	678	1.05	154	5440	436	
43d Pl. (B)	2.42	835	1.63	654	5460	2880	
44th St. (C)	1.55	1487	0.24	783	6220	507	
H. Boore & Co.	....	....	....	....	....	....	
Boyd-Lunham	0.67	654	....	....	1180	....	
Brennan Packing Co.	0.41	1408	....	....	1025	....	
Chicago Packing Co.	0.22	1128	....	....	670	....	
Darling Glue Factory	0.23	873	....	....	540	....	
Friedman Mfg. Co.	0.13	2320	....	....	815	....	
Henry Guth	0.04	2838	....	....	308	....	
G. H. Hammond							
Catch Basin (A)	0.51	385	0.02	245	530	13	
South Sewer (B)	0.75	564	0.60	299	1140	485	
Independent Packing Co.	0.38	1196	....	....	1220	....	
Libby McNeill & Libby	0.41	2770	....	....	3060	....	Includes only
Miller & Hart	0.20	1198	....	....	656	....	cook water
Morris & Co.							
Hog Plant	0.94	930	0.34	116	2360	106	
42nd St. 6/8, 9, 10	1.30	779	0.95	202	2740	517	Run with Swifts test
42nd St.	0.79	803	0.0	....	1710	....	Regular test. No
44th St.	0.71	1123	0.24	686	2150	446	night flow
Ammonia Plant	0.03	65920	....	....	5930	....	Estimated flow for 12 hr.
Northwestern Glue Co.	0.18	772	....	....	375	....	
Peoples Packing Co.	0.29	1216	....	....	476	....	Flow only 6 hr.
Pfaelzer & Sons	0.20	370	....	....	200	....	
Roberts & Oake	....	....	....	....	....	....	
Siegel-Hechinger	0.09	1084	....	....	263	....	
Standard Slaught. Co.	0.03	508	....	....	46	....	
Sulzberger & Sons							
Grease Sewer	2.33	1120	1.77	960	7050	4590	Test of June 29-
Red Sewer	1.61	780	1.55	197	3390	805	30
Swift & Co.							
40th to Ashland (A)	4.14	938	2.16	222	10500	1296	
Do. Net	....	....	....	....	7440	....	A. Less Libby's
42nd to Ashland (B)	4.26	1264	1.66	360	14500	1610	
Do. Net	....	....	....	....	11760	1093	B. Less Morris' 42nd.
Packers Ave. (C)	0.61	620	....	....	1020	....	
41st to Center (D)	1.87	399	....	....	2020	....	
42nd to Center (E)	1.39	928	....	....	3480	....	
Wool House (F)	1.46	1205	....	....	4760	....	
Western Packing Co.							
Catch Basin (A)	0.23	994	....	....	616	....	
Wash water, etc. (B)	0.55	257	....	....	381	....	
Swift, 40th St.	2.86	....	....	....	....	....	Readings taken with Libbys.
Halsted St.	....	....	....	....	2799	....	
Center Ave.	....	....	....	....	28974	4427	Summation of
Ashland Ave.	....	....	....	....	43660	8747	separate items
River	....	....	....	....	4240	484	
35th St.	....	....	....	....	263	....	
Ashland Ave.	27.9	834	18.5	279	62750	13950	May 18, 19, 20, 1911.
Center Ave.	25.8	673	16.9	155	47000	7060	May 16, 17, 18, 1911.

Total pounds dry suspended solids per 24 hr. from packers 93,594.

every case show a content of suspended matter higher than city sewage. The individual results are given house by house in the appendices. The results, averaged by flows, are tabulated (table 6) for each house. The content of suspended matter was from 5 to 50 times higher than normal city sewage in Chicago. The content of oxygen consumed was also high, from 4 to 30 times that in normal city sewage.

DETAILS. The details of the individual house investigation are noted in appendices, with a brief statement of the processes at each house, followed by a description of the test, tables giving variation of flow and suspended matter, and other data collected. This should aid the individual plant in studying its problem.

COMMENT. A study of the existing arrangements in the industries themselves, for handling conditions of the kind described herein, shows the importance of watching details. Careful scrutiny of the weak points in a house indicates that usually slightly more material can be retained by improving methods of handling somewhere. Hence, internal improvements are often as important as external, particularly in the case of the smaller houses. External treatment, however, is also necessary.

Several points stand out clearly as regards existing apparatus in Packingtown. At present none of the installations have any real settling or screening capacity. Practically all are designed from the standpoint of grease skimmers, and few are adequate even on that score. Considerable fat escapes to reach Bubbly Creek, even today.

Certain interior arrangements in houses seem desirable.

I. All roof water and clean water should be kept out of catch basins.

II. Special runs should be handled direct, as, for instance, the paunch manure. At a large plant, like the Hammond plant, a fine screen on the paunch manure outlet would remove a great deal of material now passing out and practically eliminate the labor of one man. Tank water should be evaporated, as well as all greasy liquids such as escape from Hine Bros.' rendering works.

III. More skimming area seems desirable at the plant.

IV. More skimming area is desirable at main sewer outlets.

V. At the main outlet a fine screen, preferably in duplicate, with suitable cleaning devices is requisite, in connection with a settling basin, preferably of the double deck type, regardless of whatever may be done from the grease skimming side.

Certain internal arrangements between the big and little firms might reduce the amount of material reaching the sewers, by putting the material where it can be handled. For instance, one small house, with a rendering tank, discharges tankage and tank water into the sewer after rendering. In another, blood is thrown away. In another, guts and offal are flushed out at regular intervals. If such material be collected regularly and taken to a plant for treatment, considerable improvement would accrue.

Inside the plants, care should be taken to keep material off the floors. For instance, in a small house careless handling of paunches greatly increased the amount of paunch manure reaching the floor. Tight containers easily reached are valuable.

CHAPTER III.

THE STOCKYARDS.

GENERAL. The Union Stock Yards and Transit Co. receives the live stock from the railroads. The animals are driven into pens for inspection by the buyers, and when sold are transferred to the pens under control of the particular purchaser, or else removed from the yards. There are now some 220 acres of pens in a total area of 500 acres. The older portion of the yards is built with wooden unloading platforms and runways, the newer portions being constructed of concrete, both plain and reinforced. The pens are all floored with brick. Each pen contains a watering trough. Every group of four pens, each approximately 20 by 25 feet, or an area of 2,000 square feet, is connected to a brick catch basin of the general type marked "A" in Fig. 4, of which there are over one thousand. Although a force of men is kept busy cleaning them, they frequently become clogged, even to the top. Formerly pens were used 25 by 50 feet or larger, but these have been cut up into smaller pens of late years. Most of the pens are open.

The catch basin design is very uneconomical. The settling space is only a small proportion of the entire volume. Once that is filled, the settling material will scour through. It would seem better to build catch basins with the overflow much higher up, of the type marked "B" in Fig. 4, in order to utilize fully the capacity of the catch basin.

For watering the cattle and cleaning the yards about 2,000,000 gallons of water are used daily. The manure and bedding from the

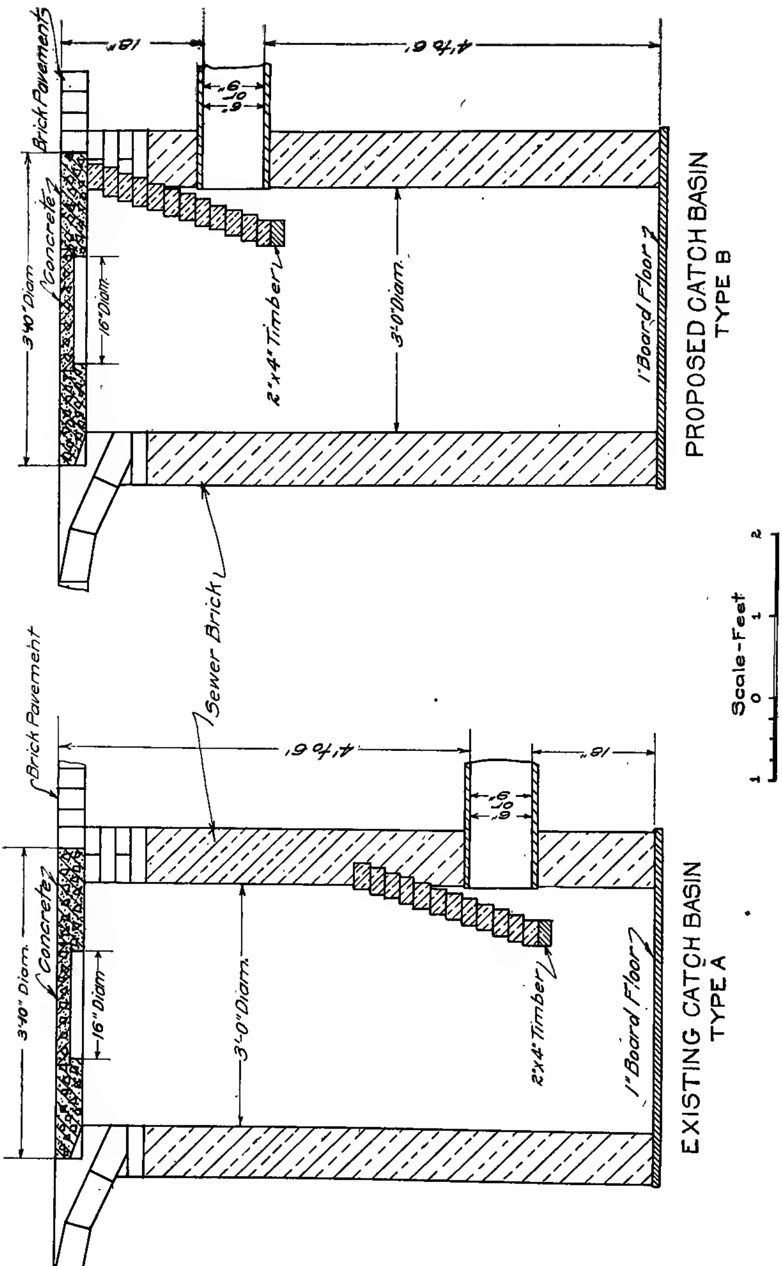


Fig. 4. Details of Catch Basin in Stockyards.

pens is sold. The urine and wash water pass through the catch basins into the branch sewer.

The stockyards are owned and operated by the Union Stock Yards and Transit Co. This company has a power plant and pumping station on Bubbly Creek, with a rapid filter plant handling water from Bubbly Creek, now operated to supply boiler feed water to the Chicago Junction Railway. A private sewer discharges direct into Bubbly Creek at Morgan street, but the other trunk sewers empty into the Center avenue sewer (Fig. 3).

STOCKYARDS TESTS. The Union Stockyards and Transit Co. co-operated in testing the waste from the Morgan street sewer. By direction of the Vice-President, Mr. Arthur G. Leonard, the superintendent of the filter plant, Mr. C. A. Jennings has worked with us in the matter and carried on tests in 1911 with an experimental settling and in 1913 and 1914 with a screening plant. Mr. Jennings, and his assistant, Mr. Goebel, have made all the analyses and measurements on the 1911 tests, the sludge analyses being made, however, in the laboratory of the Sanitary District.

EXPERIMENTAL PLANT. At the outlet of the Morgan street sewer, a timber box drain, 2 ft. 2 in. square, was connected to an orifice box, containing a 1⅜ inch standard orifice. An overflow weir, 2 feet long, measured storm flows, the ordinary dry weather flows passing over a weir 14 inches long. The orifice discharged into a tank 14 ft. 6 in. long by 3 ft. wide, by 4 ft. 2 in. deep, inside dimensions, baffled to make 3 complete settling compartments, each with an inlet near the bottom, and an outlet over a weir at the surface. The capacity was 1,332 gallons. With a flow of 26,600 gallons per 24 hours, the period in the basin was 1.21 hours.

CHARACTER OF SEWAGE. The dry weather flow from the sewer, with a drainage area of approximately 31 acres, has ranged from 0.75 to 1.67 cu. ft. per sec., or 15.5 to 34.4 cu. ft. per sec. per sq. mile. The analyses show a high content of suspended matter, consisting largely of small particles of manure, fine dust, hay, straw, etc. Fresh urine from the cattle is also present. The sewage has a very strong acrid odor, which is very persistent. The oxygen consumed is high. Typical results are given in table 7.

RESULTS OF TESTS. When operated with a nominal period of flow of 1.21 hours in the basin, and a velocity of flow of 0.6 feet per minute, at the nominal flow depth, the major portion of the suspended matter was found to deposit in the first third of the basin. The material was largely the coarser suspended matter, particles of hay, straw, manure, etc. The sludge deposited in the second and

TABLE 7.

RESULTS OF EXPERIMENTAL SETTLING TANK AT MORGAN STREET.

The Union Stock Yards & Transit Co.

Determination.	PARTS PER MILLION.						Average Percent Reduction.
	Crude Sewage.			Effluent.			
Suspended Matter	Maximum	Minimum	Average	Maximum	Minimum	Average	
Fixed	392	14	147	124	6	53	64.0
Volatile	1094	19	401	240	11	146	63.7
Total	1306	33	548	353	20	199	63.8
Oxygen consumed	361	28	202	193	24	111	44.9
Turbidity	920	47	541	780	40	362	33.0

NOTE. Length of experiment was 95 days.
Total quantity of sewage treated was 2,057,500 gallons.
Total quantity of sludge deposited was 211 cubic feet.

third compartments was very fine grained, brown in color, resembling finely separated loam (table 8). The amount was comparatively small, a total of 3.8 cu. yds. per million gallons accumulating during a period of test lasting over 3 months. The percentage of removal of suspended matter ran from —36.2 to +80.0, depending on the amount present and the condition of the basin. With a maximum of 1308 p. p. m., 73.1 per cent. was removed. With a minimum of 34 p. p. m., 41.2 per cent. was removed. On the average with a content of 548 parts per million, 63.8 per cent. was removed.

LABORATORY TESTS ON SETTLING. Laboratory tests on settling demonstrate that most of the settling suspended matter drops out in the first 5 to 10 minutes of quiescent settling.

SLUDGE. Scattered analyses (table 8) indicate a sludge somewhat more dense than the sludges from the 39th street Sewage Testing Station, the proportion of volatile matter being usually greater. The nitrogen content and fats average about the same. The sludge from the first compartment contained hair. In general, all this sludge had an offensive, putrid odor, entirely different from the material collected at 39th street.

SCREENING. In 1913, an endless band screen was installed on the outlet of the Morgan street sewer by the Union Stockyards and Transit Co. from the design of Mr. C. A. Jennings. This screen has been operated almost continuously since, various meshes and punched plates being tried. The results of the tests made by the Sanitary District are given in Chapter XI. The removal of suspended matter does not appear to be as great as by sedimentation.

CONCLUSIONS. If the sewage of the Stockyards proper be treated separately, settling basins should be built given a nominal settling period of at least 1 hour for the higher dry weather flows. Sludge storage for at least 4 cu. yds. per million gallons flow should be provided, with a period of at least 8 days, and better, 2 weeks. if arrangements are made for carefully avoiding any septic action, by cleaning very frequently. The sludge should drain readily, and after pressing can probably be burnt. The analyses show a low nitrogen content, so that utilization for fertilizer is doubtful. The appearance is also against this use. It is, however, better to build a shallow double-deck tank to aid in retaining settled matter, and obtain thereby cleaner effluents. By enlarging the sludge storage in a double deck tank, digested sludge can be had.

Fine screening is also effective but will not remove as much of the suspended matter as sedimentation. It would, therefore, seem desirable to use a combination of fine screening and settling.

TABLE 8.

ANALYSES OF SLUDGE FROM EXPERIMENTAL TANK AT MORGAN STREET.

The Union Stock Yards & Transit Co.

Date 1911	Compartment of Settling Basin.	Specific Gravity	Per Cent Moisture	Per Cent in Terms of Dry Weight.				REMARKS.
				Nitrogen.	Volatile Matter	Fixed Matter.	Ether Soluble.	
July 22	I. Inlet	1.06	80.6	1.6	59	41	2.8	Coarse. Contains hair
	I. Outlet	1.06	89.0	2.5	72	28	1.6	Coarse.
	II. Inlet	1.05	91.0	2.6	69	31	3.0	Finely divided.
	II. Outlet	1.05	89.0	3.4	56	44	3.4	
	III.	1.03	93.0	3.5	64	36	3.9	Finely divided.
Oct. 13	I.	1.05	86.0	2.2	72	28	2.1	Contains undigested grain, hair.
	II.	1.04	89.0	3.4	65	35	3.1	Finely divided.
	III.	1.16	68.0	1.0	29	71	1.2	Very coarse. Contains cinders, corn, grass.

CHAPTER IV.

DESCRIPTION OF TESTING STATION.

GENERAL. The original plant, built in 1912, consisted of a grit chamber, two settling tanks of the Dortmund and Emscher types, respectively, and six sludge filters, together with accessory

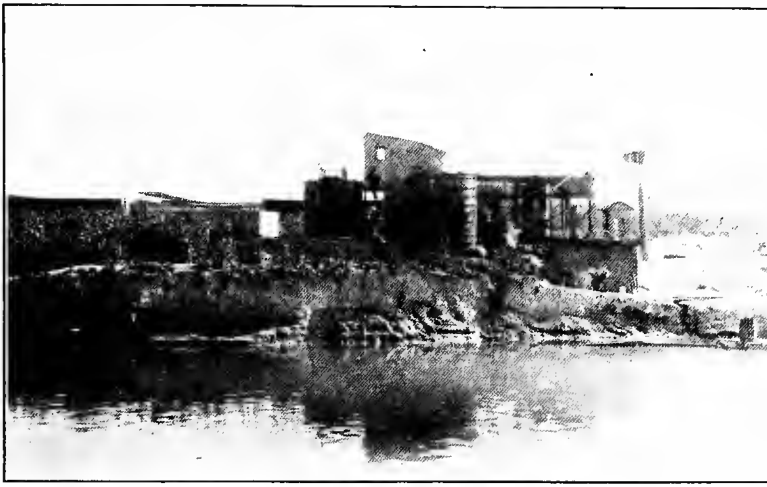


Plate 1. Center Ave. Testing Station from North.

pumping and controlling apparatus. During 1913, extensive additions were made, including a motor driven rotary screen, apparatus for determining the loss of head through screens of various mesh, a

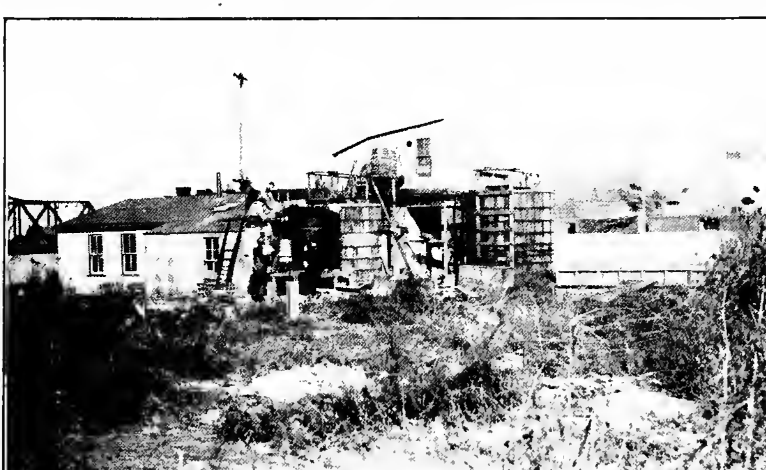


Plate 2. Center Ave. Testing Station from South.

second tank of the Dortmund type, apparatus for the application of chemicals to the sewage as an adjunct of tank treatment, a sludge press, a sprinkling filter and secondary settling basin. Additional pumping capacity was also provided. The general arrangement of

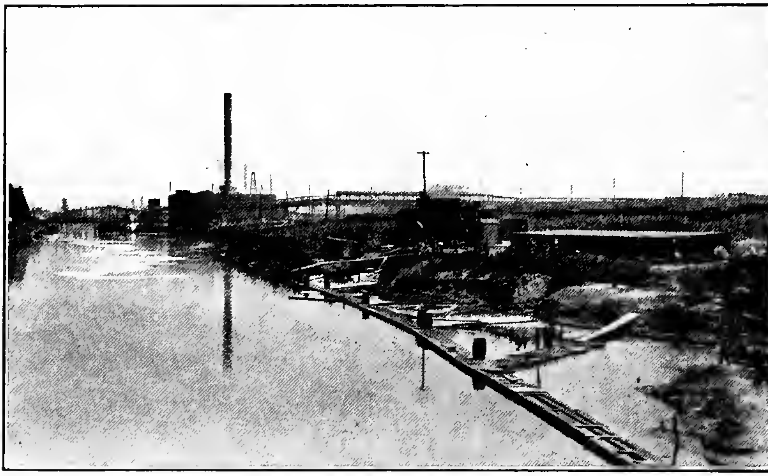


Plate 3. East Arm of South Fork of South Branch of Chicago River.
Note. View taken from Racine Ave. bridge looking East. Grease skimming basins in foreground, at outlet of Center Ave. sewer. U. S. & T. Co. power house in background .

the final plant is shown in Figs. 5 and 6, and in the accompanying illustrations, Plates 1, 2 and 3.

SUPPLY OF SEWAGE. Sewage flows by gravity through a six-inch tile pipe from the Center avenue sewer, at a point about one foot above the invert, and discharges through a six-inch shear gate into a concrete channel in the pump well. Any surplus over pumpage discharges over a waste weir at one side of the channel into a drain to the river. All sewage pumped passes through a screen, inclined at an angle of 30 degrees with the horizontal in the direction of flow, composed of ⅝-inch round bars set with ⅝-inch clear openings. The screen is 9⅜ inches wide. It was cleaned from time to time with a rake. A vertical centrifugal pump with a rated capacity of about 250,000 gallons per day discharges through a 4-inch force main with branches to the grit chamber and screen house. The pump is direct connected to a $3\frac{1}{2}$ h.-p., 3 phase, 60 cycle, 220-volt induction motor running at a speed of approximately 850 r. p. m. located in a small wooden shed covered with corrugated galvanized iron built directly over the pump-well. This arrangement keeps the motor and controlling switch dry and in good working order at all times, with excellent operating results. The pump works against a

maximum static head of about 19 feet, and, being always submerged, requires no priming device or foot valve.

In order to operate the rotary screen at a high rate without shutting down the rest of the plant, a 2½-inch Morris horizontal centrifugal pump was provided, of a nominal capacity of 260,000 gallons per day at 720 r. p. m., connecting with the force main of the original installation for flexibility of operation. The pump is belt connected to a 3 h.-p., 60 cycle, 3 phase induction motor, with a speed of 1,800 r. p. m., mounted on the floor of the motor house.

GRIT CHAMBER. One branch of the force main discharges into a stilling basin built of a half barrel, carried by the trestle supporting the grit chamber. As the speed of the motor is constant, the pumpage is regulated by a valve in the force main. The stilling basin feeds the grit chamber proper through a 4-inch pipe, entering at the bottom near one end. The grit chamber is of tank construction, of 2-inch stock, 20 ft. 6 in. long, 6 in. wide inside, varying uniformly from a depth of 19 in. at the inlet end to 13 in. at the outlet. Sludge is removed when cleaning through a 4-inch waste pipe and valve near the inlet end.

During November, 1912, a thick, greasy scum persisted on the surface of the grit chamber. To retain this, a scum board was placed 6 in. from the outlet, dipping about 2 in. below the surface of the sewage. Ordinarily the surface of the sewage is about 2½ in. below the top of the chamber, giving a capacity of about 87 gallons. The effluent flows through an open wooden flume, 6 in. square inside, to the controlling apparatus.

CONTROLLING APPARATUS. The controlling apparatus is housed in a two-story frame building, covered with corrugated galvanized iron, 8 ft. by 10 ft. in plan. The flume from the grit chamber enters the second story and discharges directly into the main orifice box, of standard tank construction, containing three compartments for vertical orifice plates, on which the head is maintained practically constant by a waste weir extending the entire length of the orifice box. The surplus sewage passes through a 3½-in. pipe overflow to the floor below. The orifices are always operated submerged, the effective head being regulated by adjustable brass weirs. The orifice compartments discharge directly into open wooden flumes, 3½ in. wide inside, leading to the various tanks. All waste from the overflow pipe is measured by an orifice box, containing three 1⅜-in. horizontal circular orifices, the head being read hourly to determine the total amount of sewage passing the grit chamber.

OLD DORTMUND TANK (TANK D). This tank, located just east of the control house, is a circular wooden tank (Fig. 7), with an inside diameter of 10 ft. and a total depth of 15 ft. 2½ in. below the

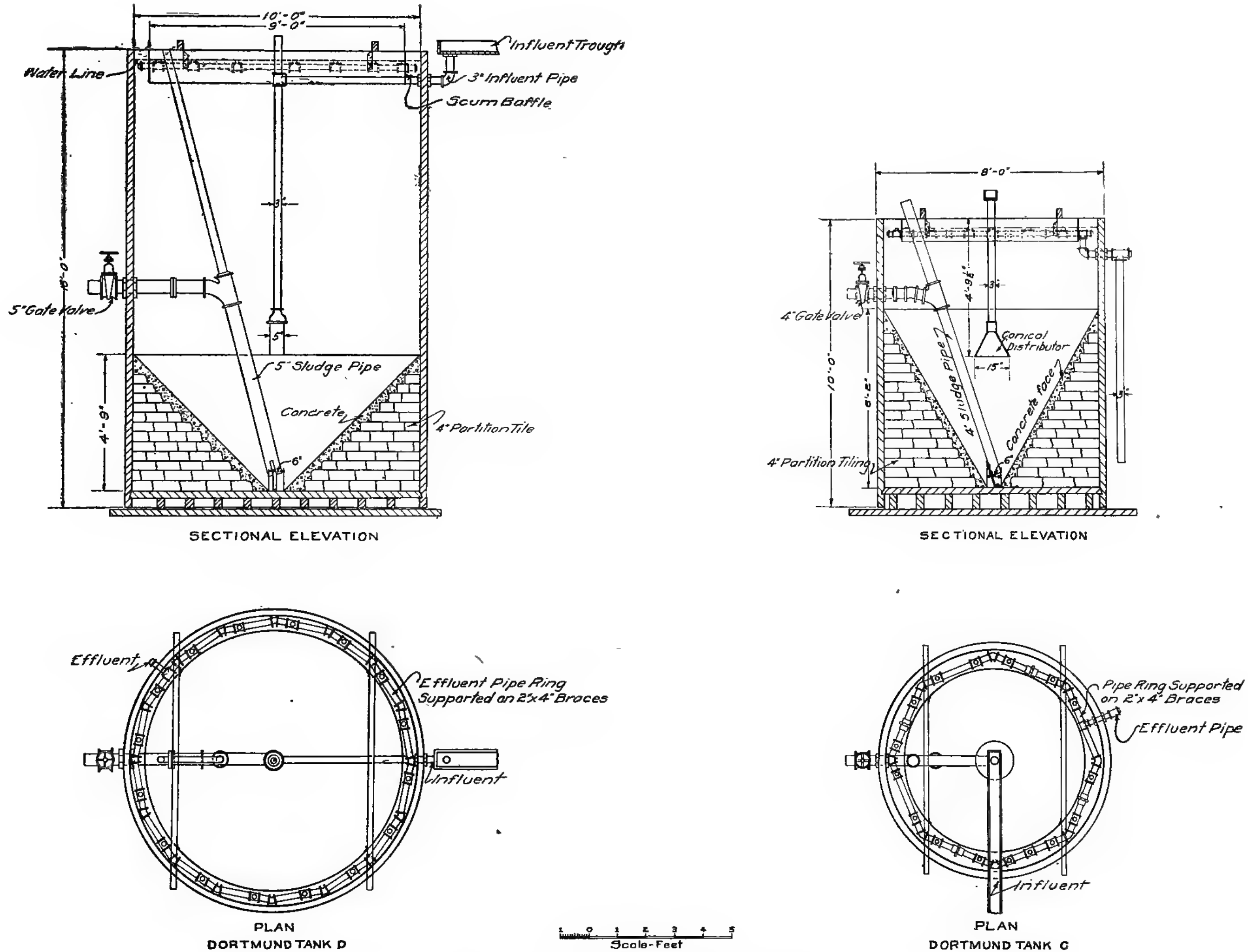


Fig. 7. Details of Dortmund Tanks.

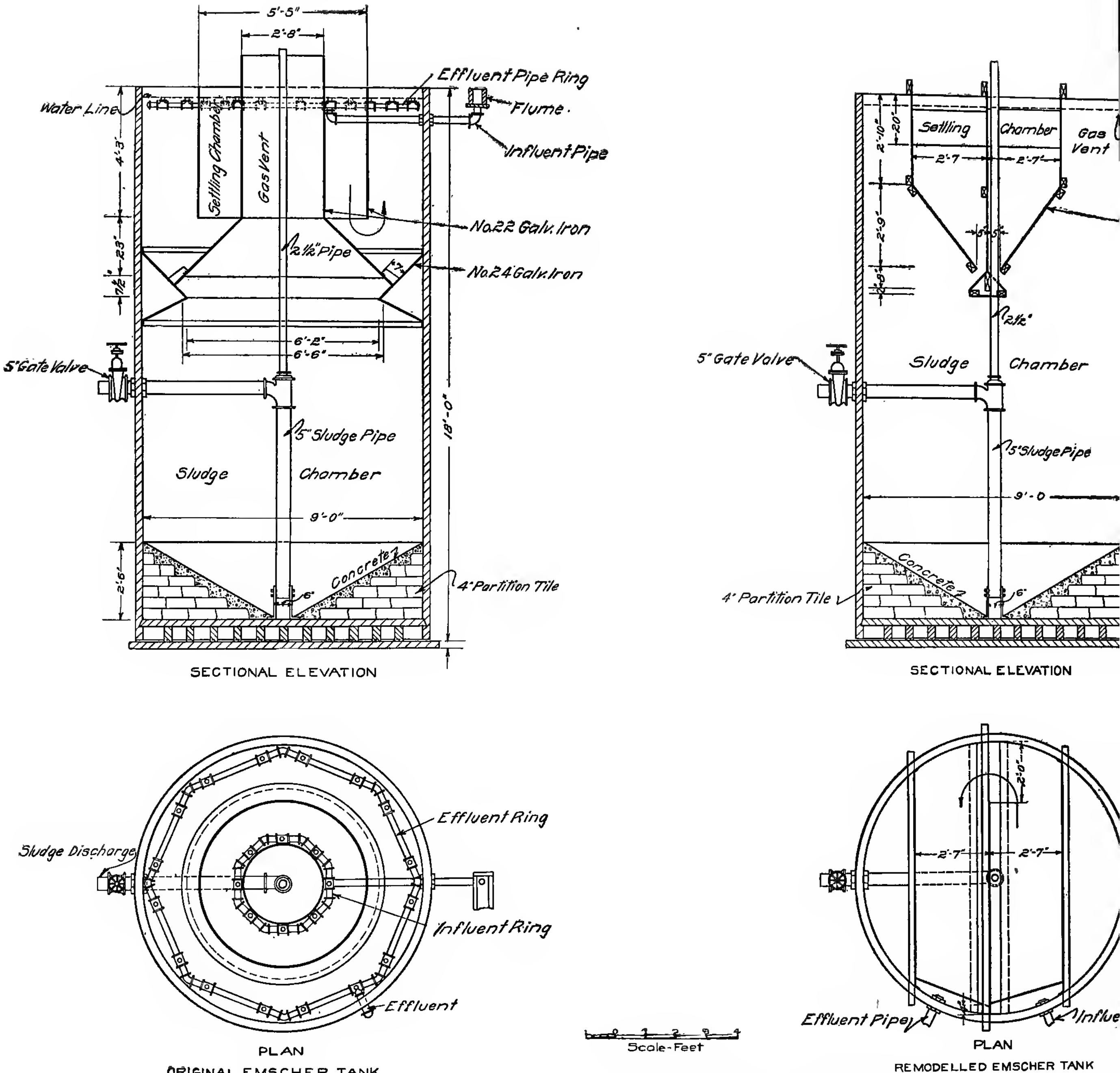


Fig. 8. Details of Original and Remodeled Emscher Tanks.

flow line, substantially built of fir staves 1¾ in. thick. Sewage enters at the center of the tank through a 3-inch pipe, increasing to a 5-in. diameter at the discharge, 4 ft. 9 in. above the bottom. The effluent is skimmed off by a pipe ring near the outside of the tank, through 16 adjustable upstanding 1½-in. nipples, equally spaced.

Sludge is removed from the bottom of the tank by a 5-in. pipe controlled by a valve. Ample head to maintain the flow of sludge is available. The hopper bottom is built up with 4 in. by 12 in. partition tile laid in cement mortar, plastered over with concrete and mortar to form an inverted cone with a slope of 45 degrees.

At the start considerable trouble was caused by the formation of a heavy scum on the surface, portions of which passed off with the effluent. To retain scum, a circular sheet-iron baffle was installed just inside the effluent ring on November 9, 1912. The settling capacity of the tank above the top of the cone is 6,120 gallons, while the sludge capacity of the hopper portion is about 980 gallons.

NEW DORTMUND TANK (TANK C). The new Dortmund tank, located south of the control house, is similar in construction to the old tank, although somewhat smaller (Fig. 7), being 7 ft. 8 in. internal diameter, and 9 ft. 2 in. deep below the water line. The conical bottom is steeper, having a slope of 60 degrees with the horizontal, and the influent pipe is provided with a 15-in. conical distributor. The effluent is collected through a pipe ring with 16 upstanding 1½-in. nipples, protected by a circumferential scum baffle just inside the effluent ring. Sludge is removed through a sludge discharge pipe controlled by a valve, as in the old tank. There is a sludge storage capacity to the bottom of the inlet pipe of about 293 gallons, and a settling capacity above this height of 1,453 gallons.

EMSCHER TANK (TANK E). This tank (Fig. 8), located north of the control house, is built of 2⅝-in. fir staves, with an inside diameter of 9 ft. and has a total depth below the flow line of 17 ft.

Originally, the tank was of the radial flow type, with an upper, or settling chamber and a lower or sludge digestion compartment. Sewage entered at the center through a small pipe ring, with eight outlet nipples, passing radially downward and under a baffle, and rising to the peripheral effluent ring. The settling solids, passing into the lower compartment, were automatically trapped. A central gas vent provided for the escape of the gases of decomposition. In March, 1914, the tank was remodelled into a horizontal flow tank.

The original tank had a settling capacity of about 2,240 gallons

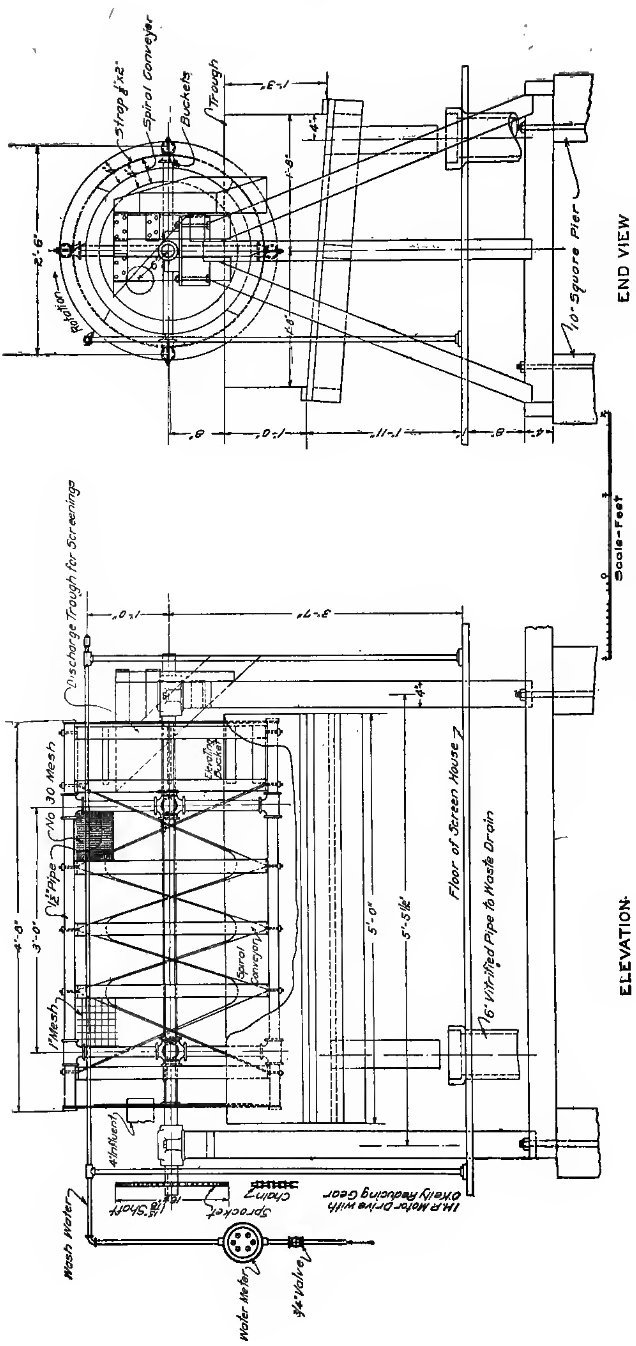


Fig. 9. Rotary Screen.

and a sludge capacity of 4,160 gallons,—a ratio of 1 to 1.85. In the remodelled tank, the settling capacity was reduced to 1,190 gallons, increasing the sludge storage to 4,390 gallons. This gives a ratio of 1 to 3.69. The gas vent of the original installation was 8.8 per cent. of the total tank area but in the remodelled tank this was increased to 34 per cent.

SLUDGE BEDS. The sludge beds, located east of the Emscher tank, are built up of 2-in. dressed lumber. Each of the original six beds was 7 ft. 9 in. square, although later several were sub-divided. The bottom is sloped about 2 inches from the sides toward the 1¼-in. underdrain at the center. The filtering material consists of approximately 5 inches of graded gravel overlaid by 1 to 2 inches of torpedo sand. The total height of beds above the sand layer is two feet.

SCREEN HOUSE. The rotary screen, loss of head apparatus, and the motor and pump controlling the lime feed in the chemical precipitation experiments are housed in a one-story wooden frame building, covered with corrugated galvanized iron 12 ft. by 20 ft. in plan, located just south of the grit chamber. Sewage for the screening experiments is supplied through a 4-in. pipe, to the main orifice box, provided with a horizontal orifice plate, a constant head being maintained by a 3½-in. overflow nipple, the surplus passing to the waste drain. The orifices feed into a galvanized iron can directly to the rotary screen or loss of head apparatus, as desired.

ROTARY SCREEN. The rotary screen (Fig. 9) is cylindrical in shape, 4 ft. 8 in. long with an effective diameter of 2 ft. 4 in., built upon a frame of 1½-in. pipe and fittings, kept in shape by bands of strap iron bolted on. The frame is covered with a brass screen of 1-in. mesh, supporting the fine brass screen with approximately 30 meshes to the lineal inch. The whole is mounted on a horizontal shaft, running in bearings set on "A" frame supports, driven by a 1 h.-p., 3 phase induction motor, geared down to about seven revolutions per minute.

The raw sewage enters the screen at one end through a 4-in. pipe. Screened sewage drops into a waste can of galvanized iron mounted below, discharging into the drain. A spiral conveyor of galvanized iron, 4 in. wide, is mounted inside the screen and pushes the material screened from the sewage toward the outlet end, where it is picked up in elevating buckets, discharging into a hopper for removal. Water was used to clean the screen and prevent clogging. A more detailed description of the methods of cleaning will be found, however, under the record of screen experiments.

SPRINKLING FILTER. The sprinkling filter is located east of the new Dortmund tank, and was built almost entirely in cut to

secure the necessary head for operating the nozzle by gravity. The filter is 14 ft. 9 in. square inside, built up of 2-in. dressed lumber thoroughly braced and tied together with iron bolts and tie rods, and surrounded by a galvanized iron wind shield 3½ ft. high. The underdrains are made by channels formed of 2 by 6 in. timbers standing on edge, with sloping concrete bottoms between, draining to a central effluent channel. A false bottom of 2 by 4 in. lumber, spaced 6 in. on centers, rests on the effluent channels. The filter is so constructed that the under drains may be either left open at the ends for aeration or closed. The filtering material consists of 6 inches of 2 to 4 in. stone overlaid by 5 ft. 6 in. of 1¼ to 2-in. stone. Considerable difficulty in securing suitable stone was encountered, thorough washing being necessary to remove the large amounts of dust present.

The filter receives the effluent from the Emscher tank, measured by an orifice box on the second floor of the control house, containing a screen with 12 meshes to the linear inch, which catches any material tending to clog the filter nozzle. The orifice box feeds a storage can which provides the fluctuations in flow during the dosing cycle of the filter, supplying a filter nozzle of the Taylor type, throwing a circular spray.

To secure a uniform distribution over the surface of the filter, the nozzle pressure is varied by rotating slightly a butterfly valve in the supply pipe between the storage can and the filter. This valve is actuated by a link motion connected to a lever, hinged at one end to the wall and bearing on a cam mounted on a horizontal shaft driven by a 1/6 h.-p. induction motor through a reduction gear, with a ratio of 900 to 1, and a chain and sprocket drive arranged to give a final speed of about one revolution in 5 minutes. The cam is designed to give a practically uniform distribution of sewage over the surface of the filter during a complete revolution.

The filter is 14 ft. 9 in. square, having a superficial area of 0.005 acre, but as the nozzle throws a circular spray, the effective area is taken at 0.004 acre.

SECONDARY SETTLING BASIN. At the start the effluent from the filter was discharged without further treatment. But as the suspended matter was uniformly high, a secondary settling basin was placed in service, November 25, 1913, built of galvanized iron 3 ft. in diameter, with an effective depth of 5 ft. 9 in. The bottom is conical, sloping at an angle of about 48 degrees with the horizontal toward a central sump 6 in. deep and 9 in. diameter. The effluent is collected by a gutter around the inside of the tank, discharging to the waste drain. The basin is operated on the vertical flow plan, the filter effluent entering by a 1½-in. pipe at the center and thence

rising to the effluent gutter. The inlet pipe originally entered 2 ft. 5 in. below the flow line, but was increased in length to 3 ft. 7 in. when the rate on the filter was increased in April, 1914.

CHEMICAL PRECIPITATION. Experiments on the chemical precipitation of sewage, begun during the summer of 1913, necessitated special apparatus. Lime being one of the precipitants employed, a circular wooden tank 4 ft. 8 in. inside diameter and 3 ft. 6 in. deep inside, was erected just east of the screen house for mixing purposes, the lime being applied in the form of milk of lime. The solution is agitated by a stirring device consisting of two paddles mounted horizontally, belt driven through a worm and gear by a 1 h.-p. induction motor, which also drives a 1½-in. centrifugal pump which elevates the solution to the point of application. Both pump and motor are placed in the screen house.

The precipitant is hand mixed in two barrels holding about 50 gallons each, feeding directly to the regulating device by gravity. The rate of application of the chemicals is controlled by galvanized iron orifice boxes, containing thin brass tubes with holes in the sides of proper size, the tubes passing through rubber stoppers in the bottoms of the boxes. The head on the orifices is varied by sliding the tubes up or down through the rubber stoppers. As the constant level in the lime orifice box is maintained by an overflow, the lime is kept in suspension by a large pumpage, the excess returning to the solution tank. A float valve maintains a constant level in the orifice box for applying the other precipitant, iron sulphate or sulphate of alumina. The ordinary ball float valve employed at first did not prove sensitive enough to secure uniform application with the small flow required. A valve devised by Mr. C. A. Jennings, for use with hypochlorite solutions, was accordingly secured made of hard rubber, similar in principle to the ordinary type of float valve, but much more sensitive to small flows. This gave a very uniform application.

At first the chemicals were added to the sewage in the trough leading from the main orifice box to the tank, the period of mixing being very short, with a travel of less than 10 feet. More thorough mixing of the lime with the sewage proved desirable, and a mixing trough was built approximately 10 ft. long by 4 ft. wide, and 10 in. deep, built up of matched boards, and baffled inside to give a total distance of flow of about 100 feet.

MISCELLANEOUS. Experiments on loss of head through screens, pressing of sludge and rate of settling under quiescent conditions were also made. The special apparatus required for this work is described in detail under the individual experiments.

CHAPTER V.

CRUDE SEWAGE.

PHYSICAL APPEARANCE. The day sewage at the outlet of the Center avenue sewer is a deep greenish brown color, high in gross as well as colloidal suspended matter, with a strong disagreeable odor suggestive of fertilizer, entirely different from the very slight dish-water odor of the comparatively weak domestic sewage received at 39th Street pumping station. Much fatty material occurs during the daytime, a heavy scum forming on the surface of the slip, as the discharge is checked in velocity and cooled by the river water. The night and Sunday flow is light in color, low in suspended matter, and comparatively free from objectionable odor, and thus is an entirely different sewage, more nearly resembling that of domestic origin.

SAMPLING. A comprehensive system of sampling was followed. Hourly portions from the different devices were taken and composites analyzed. Owing to the marked difference in strength between the day and night sewage, separate composites were first made on crude sewage only, covering the hours between 8 A. M. and 8 P. M., and 8 P. M. and 8 A. M., these being designated hereafter as the "day" and "night" sewage. On and after January 1, 1913, this division of the sampling period was extended to the grit chamber and tank effluents, on the basis of 7 A. M. to 10 P. M., inclusive. As the result of further analysis of individual hourly samples indicated that a division of the day and night flow was more representative between the hours of 8 A. M. and 10 P. M., the day sampling schedule was again changed in February, 1913, and continued to include the hours between 8 A. M. and 10 P. M. In sampling the tanks and other devices, due allowance has always been made for the theoretical detention period, the hours noted above being followed for the crude sewage. Weighted averages of the day and night samples to give the average composition for the entire 24 hours were also made. Since Feb. 1, 1913, bi-daily samples have been analyzed, and as there is little difference between the crude sewage and grit chamber effluent, analyses of the former have been omitted since January 1, 1914.

Table 9 shows the monthly average analyses for the day, night and 24-hour samples. Owing to the marked difference in composi-

tion between the Sunday and week-day flow, analyses of the former have been omitted from the day and 24-hr. figures in order to indicate more clearly the true strength of the week-day sewage. The 24-hr. samples are somewhat misleading in that they are based on equal portions taken throughout the entire day, while the flow in the sewer actually fluctuates widely during the 24-hr. period and is greatest at the time when the sewage is strongest. The average composition, weighted for variation in flow, would therefore show a somewhat stronger sewage than does the table referred to above.

In order to clearly emphasize the unusual character of this sewage, several tables are inserted for comparative purposes. Table 10 indicates the average composition of the day sewage at Center Ave. by months, compared with that of the sewage received at the 39th St. pumping station. The great difference in strength between the two as measured by the content of organic nitrogen, oxygen

TABLE 11.

ANALYSES OF SEWAGE OF VARIOUS AMERICAN CITIES AND DAY SEWAGE AT CENTER AVE.

	Parts per Million.						
	Boston* 1905–7	Columbus† 1904–5	Waterbury‡ 1905–6	Gloversville T 1908–9	Worcester 1908	Chicago (39th St.) 1909–12	Chicago (Center Ave.) 1913 Day Sewage
Nitrogen as:							
Organic Nitrogen	9.1	9.0	14.8	23.0	....	7.8	79
Free Ammonia...	13.9	11.0	7.8	12.0	22.2	9.1	22
Nitrites.........	0.0	0.09	0.14	0.38	....	0.10	0.49
Nitrate..........	0.20	0.20	1.52	0.88	....	0.33	3.04
Oxygen Consumed..	56F	51P	46F	95F	117	43	268
Chlorine..........	2300L	65	48	158	57	40	1100
Suspended Matter:							
Total..........	135	209	165	406	258	144	605
Volatile.........	91	79	115	229	166	90	461
Fixed..........	44	130	50	177	92	54	144
Alkalinity.........	125	350	41	233	..	212	291
Fats.............	...	25	26	48	..	23a	198aa

* From Winslow and Phelps, "Investigation on the Purification of Boston Sewage in Septic Tanks and Sprinkling Filters, Technology Quarterly, Vol. XX, No. 4, p. 410, Dec., 1907.

† Geo. A. Johnson, Report on Sewage Purification at Columbus, O., pp. 26, 34.

‡ From Gavin Taylor, Waterbury Sewage and Its Septic Action, Eng. News, Vol. 61, p. 59.

P Sample immersed in boiling water for 30 minutes.

F Sample boiled for 5 minutes.

L Chlorine from Water Supply Paper No. 185, (U. S. Geol. Survey), pp. 111-114.

T Eddy and Vrooman, Report on Sewage Purification, Gloversville, N. Y., p. 59.

a Four months.

aa One week in Mar., 1914.

TABLE 9.

MONTHLY AVERAGE ANALYSES OF CRUDE SEWAGE. CENTER AVE. TESTING STATION.

Date	Parts per Million										Sampling Period
	Nitrogen as				Oxygen Consumed, Total	Chlorine	Suspended Matter			Alkalinity as $CaCO_3$	
	Total Organic	Free Ammonia	Nitrites	Nitrates			Total	Volatile	Fixed		
					DAY SEWAGE—SUNDAYS OMITTED.						
1912											
Oct.	105	23	.44	1.64	282	1078	719	599	120	326	8 a. m. to 7 p. m. (Incl.
Nov.	127	28	.53	2.46	339	1190	769	590	179	342	"
Dec. 1–9 and 24–31	119	26	.44	3.43	342	1125	731	576	155	305	"
1913											
Jan.	96	24	.44	3.14	322	....	702	543	159	...	7 a. m. to 10 p. m. (Incl.)
Feb.	91	25	.50	3.22	317	....	660	510	150	...	8 a. m. to 10 p. m. (Incl.)
Mar. 1–12 and 24–31	71	19	.49	2.97	267	996	591	451	140	291	"
Apr.	70	20	.51	2.91	250	1150	556	422	134	293	"
May	80	22	.64	2.97	258	1134	658	470	188	291	"
June	81	21	.64	2.96	264	1121	603	428	175	248	"
July	71	21	.51	3.47	240	1096	568	428	140	274	"
Aug.	74	22	.47	3.13	228	1110	574	413	161	304	"
Sept.	76	21	.49	2.85	250	1128	621	498	123	319	"
Oct.	69	22	.38	2.41	251	1023	519	415	104	246	"
Nov.	86	24	.44	3.00	282	1072	617	481	136	310	"
Dec.	89	24	.38	3.70	287	1170	595	476	119	331	"
Average, 1913	79	22	.49	3.04	268	1100	605	461	144	291	"
					NIGHT SEWAGE—SUNDAYS INCLUDED.						
1912											
Oct.	49	17	.27	1.09	149	715	415	320	95	276	8 p. m. to 7 a. m. Incl.
Nov.	50	22	.20	1.28	142	800	363	238	125	259	"
Dec. 1–9; 24–31	52	20	.21	1.30	131	655	334	244	90	222	"
1913											
Jan.	..	..	...	....	...	...	225	152	73	...	11 p. m. to 6 a. m. Incl.
Feb.	..	..	...	....	...	...	167	117	50	...	11 p. m. to 7 a. m. Incl.
Mar. 1–8; 24–31	..	..	...	....	...	...	163	116	47	...	"
Apr.	..	..	...	....	...	...	121	84	37	...	"
May	..	..	...	....	...	...	238	146	82	...	"
June	..	..	...	....	...	...	162	103	59	...	"
July	..	..	...	....	...	...	148	92	56	...	"
Aug.	..	..	...	....	...	...	142	95	47	...	"
Sept.	..	..	...	....	...	...	153	110	43	...	"
Oct.	..	..	...	....	...	...	128	93	35	...	"
Nov.	..	..	...	....	...	...	148	107	41	...	"
Dec.	..	..	...	....	...	...	165	120	45	...	"
Average, 1913	..	..	...	....	...	...	163	112	51	...	

DAY AND NIGHT (24 HOUR) SEWAGE—SUNDAYS OMITTED.

1912										
Oct.	90	22	.40	1.43	248	1000	643	519	124	314
Nov.	94	26	.37	2.21	253	1037	589	431	158	314
Dec. 1–9 and 24–31	89	24	.35	1.92	252	910	540	420	120	265
1913										
Jan.	..	..	...	....	...	....	542	413	129	...
Feb.	..	..	...	....	...	....	483	366	117	...
Mar. 1–8 and 24–31	..	..	...	....	...	....	433	329	104	...
Apr.	..	..	...	....	...	....	394	296	98	...
May	..	..	...	....	...	....	500	350	150	...
June	..	..	...	....	...	....	444	310	134	...
July	..	..	...	....	...	....	418	312	106	...
Aug.	..	..	...	....	...	....	425	302	123	...
Sept.	..	..	...	....	...	....	437	350	87	...
Oct.	..	..	...	....	...	....	374	295	79	...
Nov.	..	..	...	....	...	....	444	343	101	...
Dec.	..	..	...	....	...	....	436	345	91	...
Average, 1913	..	..	...	....	...	....	444	334	110	...

TABLE 10.

MONTHLY AVERAGE ANALYSES OF SEWAGE AT CENTER AVE. TESTING STATION AND 39th ST.

Date 1912–13	Parts Per Million: Nitrogen as Total Organic	Nitrogen as Free Ammonia	Nitrogen as Nitrites	Nitrogen as Nitrates	Oxygen Consumed Total	Chlorine	Suspended Matter: Total	Suspended Matter: Volatile	Suspended Matter: Fixed	Alkalinity in Terms of CaCo₃
	DAY SEWAGE—CENTER AVE.—SUNDAYS OMITTED									
1912										
October	105	23	.44	1.64	282	1078	719	599	120	326
November	127	28	.53	2.46	339	1190	769	590	179	342
December	119	26	.44	3.43	342	1125	731	576	155	305
1913										
January	96	24	.44	3.14	322	....	702	543	159	....
February	91	25	.50	3.22	317	....	660	510	150	...
March 1–12 and 24–31	71	19	.49	2.97	267	996	591	451	140	291
April	70	20	.51	2.91	250	1150	556	422	134	293
May	80	22	.64	2.97	258	1134	658	470	188	291
June	81	21	.64	2.96	264	1121	603	428	175	248
July	71	21	.51	3.17	240	1096	568	428	140	274
August	74	22	.47	3.13	228	1110	574	413	161	304
September	76	21	.49	2.85	250	1128	621	498	123	319
October	69	22	.38	2.41	251	1023	519	415	104	246
November	86	24	.44	3.00	282	1072	617	481	136	310
December	86	24	.38	3.70	287	1170	595	476	119	331
Average, 1913	79	22	.49	3.04	268	1100	605	461	144	291
	DAY AND NIGHT SEWAGE—39th ST.—SUNDAYS INCLUDED.									
1912										
October	8.2	10	.07	.09	44	40	156	103	53	209
November	5.9	11	.11	.18	40	39	147	84	63	210
December	7.7	12	.13	.19	43	39	140	100	40	203
1913										
January	6.9	10.2	.10	.28	41	37	143	94	49	192
February	6.3	9.7	.09	.26	41	33	117	83	34	196
March	6.5	7.9	.13	.24	38	36	139	79	60	190
April	6.7	7.5	.15	.73	37	41	129	81	48	213
May	6.6	7.7	.18	.37	34	39	164	87	77	205
June	6.8	8.5	.12	.16	33	47	109	66	43	215
July	...	...	.07	.12	..	43	136	84	52	203
August	...	...	.02	.06	..	42	141	88	52	193
September	...	...	.04	.04	..	35	153	91	62	185
October	...	...	.06	.15	..	35	114	71	43	190
November	...	...	.09	.24	..	33	121	69	52	193
December	...	...	.09	.26	..	35	110	74	36	200

consumed, and suspended matter is at once apparent. Table 11, compiled from various sources, gives the average composition of sewage of various American cities. With the exception of Gloversville, which is sewered almost completely on the separate system, and Worcester, with somewhat more than half the sewers on the separate plan, the sewer systems of these cities receive both domestic sewage and storm water. The strength of sewage at Gloversville is considerably increased by the presence of large amounts of tannery wastes, and in this respect more closely approaches the sewage received at the Center Ave. testing station. The Worcester sewage also is to some extent influenced by manufacturing wastes, whereas the sewage of the other cities is essentially domestic in its origin. The great influence of the wastes from the Stockyards and Packingtown is clearly shown, making the day sewage extremely high in organic content and of unusual strength, wholly unlike the sewáge of American cities not containing large amounts of trade wastes.

HOURLY VARIATIONS IN STRENGTH. The wide difference between the day and night flow has already been noted. The suspended matter in the day sewage is 4 to 5 times higher than in the 39th St. sewage, and the organic nitrogen and oxygen consumed are even greater. On the other hand, the night sewage is comparatively weak, resembling the 39th St. sewage closely in content of suspended matter. The results of the first three months of operation are somewhat misleading, as the last of the heavy day sewage was included in the night sample, thereby increasing slightly its apparent strength. With the more accurate sampling periods adopted in 1913, the difference between the day and night flow is sharply accentuated. The hourly variation in strength may be traced closely by the averages of a series of samples, covering 4 hour periods, taken between September 16 and 26, 1912 (table 12):

TABLE 12.

CRUDE SEWAGE. HOURLY VARIATIONS IN SUSPENDED MATTER.

	12 Mid. to 3 A.M.	4 A.M. to 7 A.M	8 A.M. to 11 A.M.	12 Noon to 3 P.M.	4 P.M. to 7 P.M.	8 P.M. to 11 P.M.	Average
	Parts Per Million.						
Total	123	316	608	785	717	287	473
Volatile ..	81	240	470	614	557	193	359
Fixed	42	76	138	171	160	94	114

The hourly variation of the 39th Street sewage is much less, a series of tests conducted on January 25 and 26, 1911, showing a minimum of 105 and a maximum of 151 parts per mil. of suspended matter.

DAILY VARIATIONS. Owing to the general cessation of work in the Yards on Sunday, the Sunday sewage varies little throughout the entire 24 hours and is similar in composition to the night sewage on week days. The monthly averages for Sundays are indicated in Table 13. Some fluctuation in strength throughout the week appears in the daily analyses but in general these follow no regular cycle, and are probably due not only to actual differences in strength from day to day, but also, to a certain extent, to unavoidable errors of sampling.

TABLE 13.

CRUDE SEWAGE AT CENTER AVE. TESTING STATION.

MONTHLY AVERAGE ANALYSES OF SUSPENDED MATTER ON SUNDAYS.

Date	Parts per Million						Remarks.
	Day Sample			Day & Night Sample			
	Total	Vol.	Fixed	Total	Vol.	Fixed	
1912							
October.	210	200	10	148	123	25	Day Samp. 8 a.m. to 7 p.m. Inc.
November. . .	135	117	18	125	97	28	" " " "
December. . .	175	122	53	153	110	43	" " " "
1913							
January.	214	127	87	224	132	92	Day Samp. 7 a.m. to 10 p.m. Inc
February. . . .	174	102	72	151	89	62	" " 8 a.m. to 10 p.m. Inc
March.	175	120	55	187	123	64	" " " "
April.	148	102	46	133	88	45	" " " "
May.	201	137	64	189	123	66	" " " "
June.	196	151	45	151	110	41	" " " "
July.	216	130	86	238	127	111	" " " "
August.	238	154	84	171	111	60	" " " "
September. . .	163	145	18	212	143	69	" " " "
October.	232	175	57	184	138	46	" " " "
November. . .	300	227	73	221	163	58	" " " "
December. . .	256	193	63	203	150	53	" " " "
Av. 1913. . . .	209	147	62	189	125	64	

The fluctuation in strength is usually greater in the night samples, probably because the flow of heavy day sewage may extend longer into the evening than usual, some being included in the night sample.

SEASONAL VARIATIONS IN STRENGTH. The monthly

averages indicate the sewage to have a maximum strength during the fall and early winter, falling off to a minimum in April. The figures for the day sewage in 1912 are not strictly comparable with the other analyses, owing to the different period of sampling. In the investigation of the individual packing houses during the summer of 1911, the volume of slaughtering was found to vary considerably with the seasons (Fig. 2), the maximum kill being reached in the fall and early winter, with the minimum in the spring or summer. The strength of the sewage varies in the same way, the seasonal fluctuations following roughly the amount of slaughtering and packing in the packing houses.

ORGANIC NITROGEN. The amount of organic nitrogenous matter is extraordinarily high, as shown by the organic nitrogen content. The average for the domestic 39th St. sewage during the years 1909 to 1912 has been 7.8 p. p. m., whereas the sewage received at the Center Ave. testing station has varied from 70 to 127 p. p. m., based on monthly averages, while the results on individual days have rarely been much below 70, and frequently have exceeded 140. Undoubtedly, a considerable portion of this nitrogenous matter is highly putrescible, increasing the potentialities for offense.

FREE AMMONIA. The free ammonia is somewhat higher than at 39th St., although in much smaller proportion than for the organic nitrogen. The area tributary to the Center Ave. sewer is small, and the period of flow short. The sewage, therefore, is comparatively fresh, with little decomposition of the nitrogenous matter. The sewage received at 39th St. is not so fresh, as the drainage area is large and the period of flow in the sewers considerable. Certain wastes discharged from Packingtown are high in ammonia. Ammonia, however, is recovered from some of the animal residues.

NITRATES AND NITRITES. Nitrites and nitrates are both high, although fluctuating considerably from day to day, possibly because of the use of saltpeter in curing and preserving. It is hardly probable that any organic matter is nitrified in the sewer.

OXYGEN CONSUMED. The sewage is very rich, not only in organic nitrogenous wastes, but also in material easily oxidizable in an acid solution of potassium permanganate. The determination was made by digesting for 30 minutes over the steam bath. The day sewage has averaged from 6 to 8 times as high in oxygen consumed as the 39th St. sewage.

CHLORINE. The chlorine content ordinarily serves as an index of the strength of a sewage. The abnormally high chlorine

here found masks the significance of this determination, because of the mixture of great quantities of animal urine with the wastes from the hide cellars and other processes where salt is used.

ALKALINITY. Glue is manufactured from the scraps of hide and other refuse at a few of the larger packing houses. From this comes large quantities of lime to increase the alkalinity of the sewage above that at 39th St.

TOTAL SOLIDS. Total solids (table 14) were determined only during a six-day run in January, 1913. For comparative purposes the suspended matter for the same period is included. About twenty per cent. of the total solids are in suspension. At 39th St. from October 5 to November 28, 1910, the total solids averaged 580 p. p. m., of which 47 per cent. was in suspension.

TABLE 14.

TOTAL SOLIDS AND SUSPENDED MATTER.
(Day Sewage 7 A.M to 10 P.M.)
Parts Per Million

Date 1913	Total Solids			Suspended Matter		
	Total	Volatile	Fixed	Total	Volatile	Fixed
Jan. 4	3838	1370	2468	530	470	160
6	3326	1230	2096	600	440	160
7	3212	1580	1632	560	470	90
8	3416	1988	1428	740	630	110
9	3100	1502	1598	720	620	100
10	3886	1820	2166	850	630	220
Average	3480	1582	1898	666	543	123

The abnormally strong character of the sewage is emphasized by these figures. Especially interesting is the total volatile matter, approximately two-thirds of which is in solution. Any process of sedimentation, however complete, will therefore leave in the sewage an excessive amount of soluble organic wastes, which probably contribute very largely to the putrescibility of the liquid.

FATS. The fat content is exceptionally high, as shown by occasional analyses (table 15).

The ether soluble content of the 39th St. sewage is from about 20 to 25 parts per million, less than one-tenth that of the day sewage at Center Ave. Most of the packing houses endeavor to recover with grease skimming basins the fats escaping with the wastes from the different processes. These basins are small and not always

TABLE 15.

CRUDE SEWAGE—ETHER SOLUBLE MATTER.

Parts Per Million.

Date, 1912	8 A. M. to 7 P. M.	8 P. M. to 7 A. M.
Nov. 30	317	99
Dec. 2	230	120
3	124	122
4	343	279
5	210	106
6	233	118
7	246	107
1914	**8 A. M. to 10 P. M.**	**11 P. M. to 7 A. M.**
Mar. 20 to 21	185	23
23 to 24	208	29
25 to 26	202	49

receive adequate attention, so considerable amounts of fat reach the sewer, in fact, sufficient to make it profitable to the packers to maintain skimming basins at the main outlet of large plants.

VOLATILE AND FIXED MATTER. In the high content of suspended matter the volatile portion is unusually large, on the day sewage averaging from 71 to 83 per cent. of the total suspended matter, based on monthly averages, being somewhat higher in winter than in summer. The night sewage has shown a somewhat smaller proportion of volatile matter, averaging 60 to 70 per cent. For the years 1909 to 1912, the 39th St. sewage contained on the average 59 per cent. of volatile matter.

TEMPERATURE OF SEWAGE. Owing to large quantities of condenser water and other hot wastes, the temperature of the sewage at the outlet is exceptionally high. Fig. 10 shows the mean daily temperature compared with that at 39th St., together with the mean daily temperature of the air taken from the records of the U. S. Weather Bureau. The sewage ranges from 5 to 20 degrees Fahr. hotter than the sewage at 39th St. This high temperature undoubtedly has an important bearing on the treatment of the liquid. The seasonal variation in general ranges from about 60 degrees Fahr. in winter to 90 degrees in summer. Particularly noteworthy is the sharp drop of 5 to 10 degrees on Sundays, clearly indicating the influence of the packing house wastes, and sharply distinguishing this sewage from the 39th St. flow. Fig. 11 shows the temperatures of the sewage at 39th St. and Center Ave., the lake and air averaged by months.

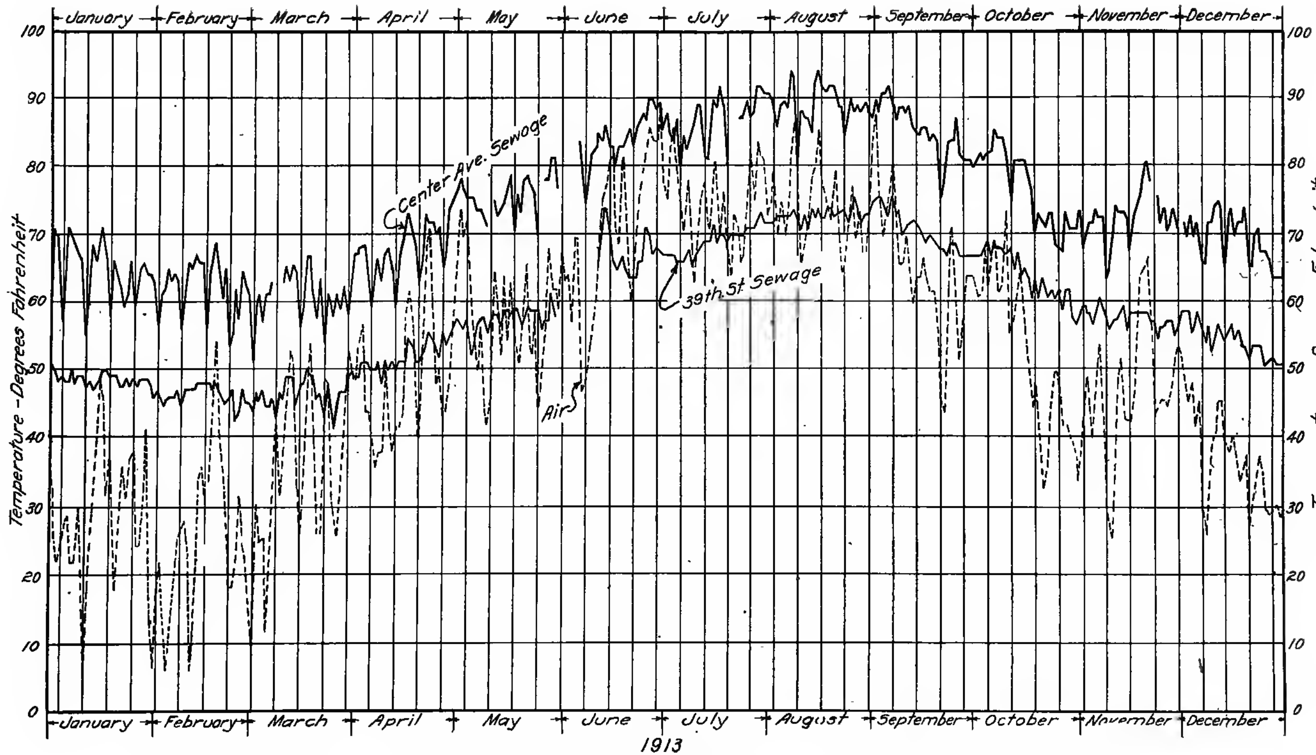


Fig. 10. Average Daily Temperatures. Air, Crude Sewage at 39th St. and Center Ave.

Note. Ordinate Lines given represent Sundays.

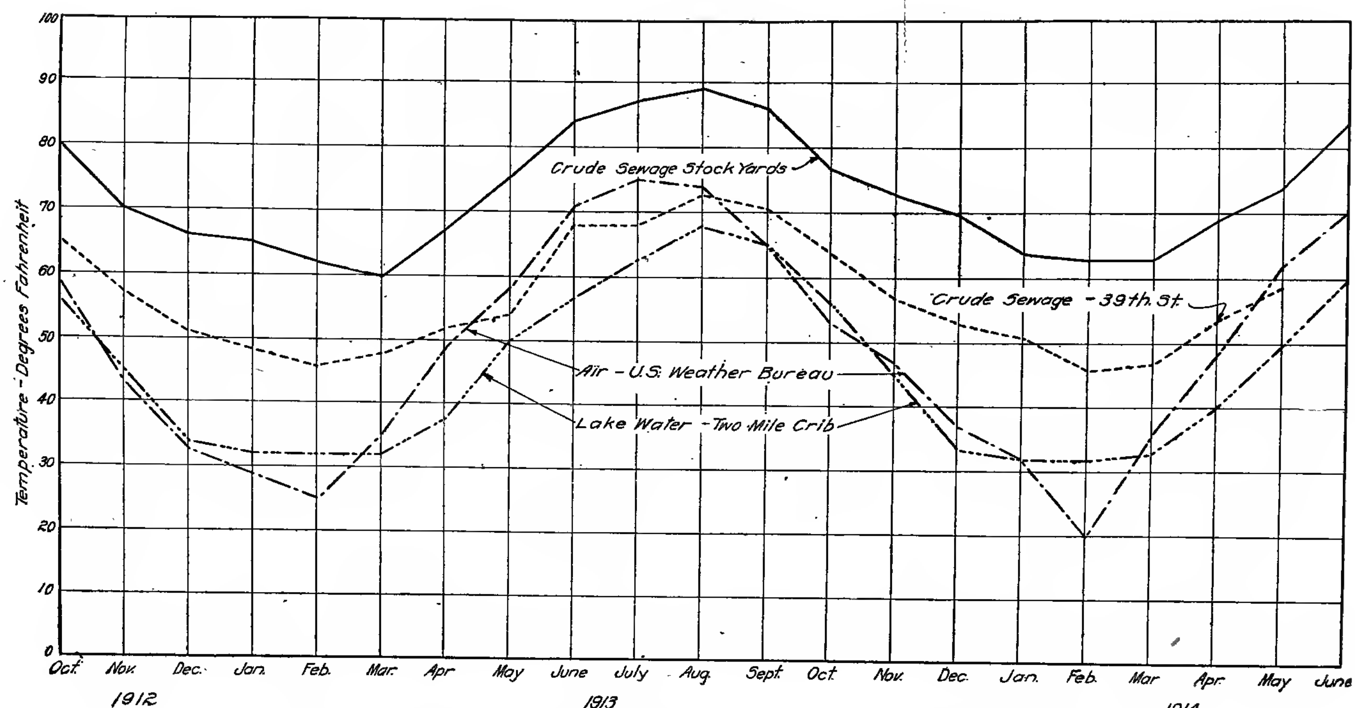


Fig. 11. Average Monthly Temperature of Air, Lake, and Crude Sewage.

Note. Crude Sewage Stock Yards is Center Ave. Sewage.

ASHLAND AVE. SEWAGE. As considerable packing house waste enters the Ashland Ave. sewer, samples were collected for two weeks in September, 1913, under identically the same conditions of sampling and division between day and night flow as at Center Ave. The results, given in table 16, and compared with similar analyses for Center Ave., show the sewages at Ashland Ave. and Center Ave. to have substantially the same composition and character. The Ashland Ave. sewage is somewhat lower in chlorine, possibly because of the absence of any urine from Stockyards drainage.

TABLE 16.

COMPARATIVE ANALYSES OF CRUDE SEWAGE FROM CENTER AVE. AND ASHLAND AVE. SEWERS.

	PARTS PER MILLION									
1913	NITROGEN AS					Chlorine	SUSPENDED MATTER			Alk. as of $CaCO_3$
	Total Org.	Free Amm.	Nitrites	Nitrates	Oxy. Con.		Total	Vol.	Fixed	
				DAY SEWAGE ASHLAND AVE.—WEEK						
Sept. 22	65	19	.16	1.48	211	850	830	560	270	400
24	83	21	.20	1.48	247	1000	810	640	170	340
26	74	22	.16	1.80	265	950	880	600	280	420
29	69	19	.24	1.46	250	880	700	520	180	330
Oct. 1	71	21	.32	1.23	267	920	1100	970	140	320
3	74	19	.16	4.40	229	940	830	650	180	340
Average	73	20	.21	1.97	245	920	860	657	203	358
				CENTER AVE.—WEEK						
Sept. 22	77	19	.52	3.26	248	1070	690	480	210	240
24	86	18	.52	2.26	275	1060	720	600	120	320
26	75	21	.52	2.74	282	1250	660	510	150	330
29	58	18	.40	1.40	221	900	450	380	70	270
Oct. 1	58	18	.32	2.09	227	850	420	410	10	240
3	73	26	.24	1.90	262	1210	670	520	150	320
Average	71	20	.42	2.27	252	1060	601	483	118	287
				ASHLAND AVE.—SUNDAY						
Sept. 28	..	..	...	....	...	...	172	108	64	...
Oct. 5	..	..	...	....	...	...	188	92	96	...
Average	..	..	...	....	...	...	180	100	80	...
				CENTER AVE.—SUNDAY						
Sept. 28	..	..	...	....	...	...	100	84	16	...
Oct. 5	..	..	...	....	...	...	88	72	16	...
Average	..	..	...	....	...	...	94	78	16	...
				NIGHT SEWAGE ASHLAND AVE.—WEEK AND SUNDAY						
Sept. 22	32	16	.06	1.33	60	500	272	128	144	230
24	34	18	.08	0.78	61	590	192	132	60	220
26	33	19	.12	0.66	81	530	360	88	272	250
28	..	..	...	....	...	...	244	116	128	...
29	35	17	.07	0.67	76	530	212	132	80	250
Average	34	18	.08	.86	70	537	258	120	138	237
				CENTER AVE.—WEEK AND SUNDAY						
Sept. 22	..	..	...	....	...	...	100	56	44	...
24	..	..	...	...	...	...	152	124	28	...
26	..	..	...	...	...	...	104	88	16	...
28	..	..	...	...	...	...	324	144	180	...
29	..	..	...	...	...	...	140	108	32	...
Average	..	..	..	...	...	...	146	99	47	...

CHAPTER VI.

GRIT CHAMBER.

GENERAL. The purpose of a grit chamber is to remove the heavy mineral matter in the sewage, especially the detritus entering the sewers at time of heavy storms, without causing deposition of organic matter, which usually can best be handled at a later stage of treatment. A comparatively high velocity is essential to prevent the settling of excessive amounts of lighter organic materials. The grit chamber was operated at a rate of from about 105,000 to 150,000 gal. daily with an average flow depth of approximately 13½ in

TABLE 17.
GRIT CHAMBER.
Sludge Accumulation and Analyses.

Date	Cu. Yd. Per Mil. Gal.		Spec. Grav.	Per Cent Moisture	Calculated to dry Weight Percentage				Remarks
	Since last cleaning	Since start			Nitrogen	Vol. Matter	Fixed Matter	Ether Soluble	
1912									
Oct. 25.....	0.016	0.016	1.31	48.3	0.72	23	77	1.7	Cleaned
Nov. 9.....	0.062	0.028	1.23	....	0.80	..	..	2.0	"
Nov. 22.....	0.025	0.027	1.12	....	1.68	58	42	2.8	"
Dec. 3*.....	0.000	0.022	....	....	....	..	..	...	"
Dec. 27.....	0.012	0.021	1.30	44.6	1.04	33	67	2.2	"
1913									
Jan. 17.....	0.032	0.023	1.24	50.7	0.88	34	66	2.1	"
Feb. 10.....	0.026	0.023	1.13	55.4	0.88	40	60	2.8	"
Apr. 9.....	0.028	0.025	1.50	34.9	0.56	13	87	1.2	"
May 1.....	0.031	0.025	1.33	50.0	0.88	30	70	1.6	"
June 24.....	0.017	0.024	1.34	44.6	0.64	17	83	1.2	"
Aug. 8.....	0.013	0.022	1.44	39.6	0.80	19	81	0.9	"
28.....	0.029	0.022	1.34	44.3	0.64	23	77	5.5	"
Oct. 2.....	0.018	0.022	1.39	29.2	0.56	10	90	1.5	"
24.....	0.022	0.022	1.36	47.8	0.76	26	74	1.6	"
Nov. 13.....	0.023	0.022	1.32	49.1	0.84	27	73	1.9	"
Dec. 10.....	0.016	0.022	1.23	54.9	0.88	34	66	1.8	"
1914									
Mar. 12.....	0.011	0.020	....	....	....	..	..	....	"
Apr. 21.....	0.044	0.021	....	....	....	..	..	...	"
June 26.....	0.019	0.021	....	....	....	..	..	...	"
Average.....	.....	.....	1.31	45.6	0.84	28	72	2.1	

* Estimated result—Sludge run out by filter attendant without measuring.

Making no allowance for the reduction of volume by deposits this variation in flow corresponds to velocities from 17 to 25 ft. per min., or from 87 to 125 mm. per sec., with a short detention period, varying between 70 and 50 sec.

SLUDGE. The grit chamber was cleaned at intervals of two to eight weeks, the amount of grit deposited being measured and sampled for analysis. These results (table 17) indicate a sludge of high specific gravity and low moisture content. The content of nitrogen and ether soluble matter was also low, approximating the grit chamber sludge at 39th St. The percentage of volatile and fixed matter varied considerably, however, at times the volatile content being very high for a true grit, and in general the percentage of volatile matter being higher than at 39th St., with the high velocities. The sludge consisted largely of black-stained sand with varying amounts of paunch manure and animal droppings.

The amount of detritus was slight, averaging about 0.021 cu. yd. per mil. gal. With an average specific gravity of 1.31 and a moisture content of 46 per cent., this corresponds to a removal of about 3 p. p. m. of suspended matter, or less than 1 per cent., based on the average composition of the raw sewage. The rate of accumulation has varied between individual cleanings. The accumulation at the 39th St. testing station at high velocities (0.016 cu. yd. per mil. gal. at 142 mm. per sec.), is lower than at the Center Ave. testing station, but the velocity was appreciably less, so that the results are not wholly comparable.

The rate of accumulation of grit was probably less than under working conditions in an actual plant receiving the entire flow of the sewer, as the pipe supplying the testing station leaves the sewer at a point above the invert, and thus may not receive its proportionate share of heavy grit from the bottom.

The sludge was simply flushed from the grit chamber into the waste pipe and discharged without further treatment. It was dry enough, however, to be handled by shoveling, and was comparatively inoffensive.

EFFLUENT. The amount of suspended material removed by the grit chamber was a very small proportion of the total suspended matter, and accordingly the reduction in suspended matter was merely nominal. Determinations of suspended matter were made, the monthly averages being given in table 18. The percentage reductions in suspended matter are rather erratic, showing an apparent increase in some months, whereas in other months the removal varies from 3 to 22 per cent. In December, 1912, to determine

TABLE 18.

GRIT CHAMBER.

Reduction in Suspended Matter, Based on Monthly Averages.

Date	Suspended Matter			Parts Per Mil.			Per Cent Reduction		
	Influent			Effluent					
	Total	Vol.	Fixed	Total	Vol.	Fixed	Total	Vol.	Fixed
1913	Day Sewage—Sundays Omitted								
Jan.	702	543	159	670	519	151	5	5	5
Feb.	660	510	150	605	455	150	8	11	0
Mar 1-8; 24-31.	591	451	140	626	484	142	6*	7*	1*
Apr.	556	422	134	523	390	133	6	8	1
May	658	470	188	597	450	147	9	4	22
June.	603	428	175	580	437	143	4	4*	18
July.	568	428	140	543	420	123	5	4	12
Aug.	574	413	161	554	406	148	3	2	8
Sept.	621	498	123	577	440	137	7	12	11*
Oct.	519	415	104	528	420	108	3*	1*	4*
Nov.	617	481	136	556	437	119	10	9	12
Dec.	595	476	119	502	400	102	16	16	14
Av. 1913.	605	461	144	572	438	134	6	5	7
	Night Sewage—Sundays Included.								
Jan.	225	152	73	204	147	57	9	3	22
Feb.	167	117	50	150	102	48	10	13	4
Mar. 1-8; 24-31.	163	116	47	157	108	49	4	7	4*
Apr.	121	84	37	125	79	46	3*	6	24*
May.	238	146	82	185	122	63	22	16	23
June.	162	103	59	156	103	53	4	0	10
July.	148	92	56	134	89	45	10	3	20
Aug.	142	95	47	136	92	44	4	3	6
Sept.	153	110	43	156	117	39	2*	6*	9
Oct.	128	93	35	130	92	38	2*	1	8*
Nov.	148	107	41	133	99	34	10	8	17
Dec.	165	120	45	160	119	41	3	1	9
Av. 1913.	163	112	51	152	106	46	7	5	10
1912	Day and Night (24 Hour) Sewage—Sundays Omitted								
Oct.	644	518	126	669	547	122	4	6*	3
Nov.	589	430	159	644	480	164	9*	12*	3*
Dec.	540	420	120	524	410	114	3	2	5
1913									
Jan.	542	413	129	517	398	119	5	4	8
Feb.	483	366	117	446	332	114	8	9	3
Mar. 1-8; 24-31.	433	329	104	456	347	109	5*	5*	5*
Apr.	394	296	98	375	275	100	5	7	2*
May.	500	350	150	445	328	117	11	6	22
June.	444	310	134	432	319	113	3	3*	16
July.	418	312	106	389	297	92	7	5	13
Aug.	425	302	123	407	296	111	4	2	10
Sept.	437	350	87	411	316	95	6	10	9*
Oct.	374	295	79	381	298	83	2*	1*	5*
Nov.	444	343	101	401	313	88	10	9	13
Dec.	436	345	91	376	298	78	14	14	14
Av. 1913.	444	334	110	420	318	102	5	5	7

Note: Day Sewage includes samples from 8 A. M. to 10 P. M. incl.
Night sewage includes samples from 11 P. M. to 7 A. M. incl.

* Denotes increase.

whether the method of sampling caused the increase in suspended matter occasionally noted, samples covering 8 hr. intervals were taken over a period of two weeks with particular care. The average results on suspended matter and chlorine are shown in table 19. Since the same discrepancies occurred, the errors previously found are probably those of sampling.

In general, a somewhat higher reduction in fixed matter was noticeable as would be expected, but this was not universally true.

TABLE 19.

SUSPENDED MATTER AND CHLORINE IN GRIT CHAMBER EFFLUENT.

Dec. 10 to 23, 1912.

8 A. M. to 4 P. M.				4 P. M. to 12 Mid.				12 Mid. to 8 A. M.			
Susp. Matter		Chlorine		Susp. Matter		Chlorine		Susp. Matter		Chlorine	
Crude	Grit	Crude	Grit	Crude	Grit	Crude	Grit	Crude	Grit	Crude	Grit
633	668	1044	1063	521	546	994	961	238	226	627	627

SCUM. About the middle of November, 1912, a heavy greasy scum formed on the surface of the grit chamber. To retain it from passing into the controlling apparatus, a baffle dipping about 2 in. below the surface was installed, 6 in. from the outlet of the chamber. The scum collected in a cream colored mat, at times covering the entire surface of the chamber to a depth of 2 in. or more. The amount accumulated, summarized by months in table 20, varies

TABLE 20.

GRIT CHAMBER, ACCUMULATION OF SCUM.

Pounds Per Million Gallons.

Date	8 a.m. to 11 p.m.	11 p.m. to 8 a.m.	8 a.m. to 8 a.m.	Remarks
1912				
Dec.	...	...	553	12 days
1913				
Jan.	...	...	633	9 days
Feb.	...	...	464	21 days
Mar.	...	...	303	
Apr.	...	...	34	
May.	...	...	47	
June.	...	...	83	
July.	163	26	111	
Aug.	5	0	5	
Sept.	12	0	12	
Oct.	240	32	162	
Nov.	885	196	625	
Dec.	1490	400	1060	
1914				
Jan.	1730	490	1260	
Feb.	1430	416	1050	
Mar.	256	108	198	
Apr.	28	0	18	
May	122	0	122	
June.	71	0	71	

considerably, but in general is much higher in winter than at other seasons of the year. The variations in temperature of the sewage and air in part cause this. The variation in amount of killing, in velocity of flow through the grit chamber occasioned by deposits of detritus, and in the care with which the grease skimming basins are operated at the individual plants all affect the formation of scum to a certain extent. Some of these factors are seasonal, while others are local. The greater part of the scum collects during the daytime. This matter is discussed at length in Chapter XIV.

Occasional analyses of the scum (table 21) show a very high percentage of volatile matter, and ether soluble material. The nitrogen content is comparatively low. Based on the average content of ether soluble matter in the dry residue and on the percentage of moisture, about 15 per cent. of the weight of wet scum accumulated represents pure fat.

TABLE 21.

GRIT CHAMBER AT CENTER AVE. TESTING STATION.

Analyses of Scum.

Date	Specific Gravity	Percent Moisture	Dry Basis—Percentage			
			Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble
1912						
Nov. 15	0.74	84.1	2.64	91.9	8.1	51.3
16	0.73	81.0	2.56	90.6	9.4	60.3
27	0.98	62.9	1.03	96.0	4.0	66.6
29	1.01	72.7	1.35	90.5	9.5	57.4
Dec. 4	0.99	73.4	1.04	91.7	8.3	62.6
13	0.99	87.4	1.98	....	....	65.2
17	0.97	71.1	....	....	....	68.6
18	0.99	74.3	....	....	....	62.3*
19	0.97	70.7	....	....	....	66.8
20	0.99	76.7	....	....	....	65.7
21	0.97	65.0	....	....	....	58.1
22	0.98	81.8	....	....	....	49.4
23	0.98	73.0	....	....	....	56.5
1913						
Feb. 26	0.97	83.8	1.68	....	....	58.8
Average	0.94	75.6	1.75	92.1	7.9	65.6

* With acidification 69 percent ether soluble.

CHAPTER VII.

PLAIN SEDIMENTATION IN DORTMUND TANKS.

(Tanks C and D.)

GENERAL. Two tanks of the Dortmund type were run as plain sedimentation tanks. Tank D was operated from the start until July 7, 1913, as a plain sedimentation tank. After that date, it was principally used for chemical precipitation. Tank C was started on June 24, 1913.

Both tanks are similar in construction and method of operation, sewage rising from a central pipe some distance above the bottom of the tank to the effluent ring near the periphery (see Fig. 7). The solid matter settles to the bottom of the tank and is removed at intervals.

The capacity of Tank D for settling above the bottom of the inlet pipe is about 6120 gal., and for sludge below the inlet approximately 980 gal. As originally operated, the influent pipe in Tank C terminated at 3 ft. 6 in. above the bottom of the tank giving a sludge capacity of about 156 gal. and a settling volume of approximately 1590 gal. On August 15, 1913, a conical distributor was added, the influent pipe being shortened to a point 4 ft. 8 in. above the bottom, increasing the sludge capacity to 293 gal. and reducing the settling capacity to 1453 gal. The operating schedules of both tanks and the theoretical velocities of flow are given in tables 22 and 23.

TABLE 22.

OPERATING SCHEDULE FOR DORTMUND TANK C.

From	To	Rate Gallons Daily	Detention Period Hour	Mean Upward Velocity		Remarks
				Ft. per Hour	Mm. per Second	
June 24, 1913	Aug. 15, 1913	18,200	2.1	1.7	0.146	
Aug. 15, 1913	Dec. 1, 1913	18,200	1.9	2.3	0.198	
Dec. 1, 1913	Jan. 5, 1914	34,800	1.0	4.5	0.387	
Jan. 5, 1914	Feb. 9, 1914	Used for chemical precipitation.				
Feb. 9, 1914	May 1, 1914	8,800	4.0	1.1	0.095	
May 1, 1914	June 1, 1914	12,000	2.9	1.5	0.129	Using screened sewage.
June 1, 1914	July 1, 1914	12,000	2.9	1.5	0.129	

TABLE 23.

OPERATING SCHEDULE FOR DORTMUND TANK D.

From	To	Rate Gallons Daily	Detention Period Hours	Mean Upward Velocity	
				Ft. per Hour	Mm. per Second
Sept. 16, 1912	Mar. 1, 1913	36,400	4.0	2.6	0.224
Mar. 1, 1913	July 7, 1913	24,200	6.0	1.7	0.146
July 7, 1913	Jan. 5, 1914	Used for chemical precipitation.			
Jan. 5, 1914	Feb. 7, 1914	14,600	10.0	1.0	0.086
Feb. 7, 1914	July 1, 1914	Used for chemical precipitation.			

ANALYTICAL RESULTS. Monthly averages of the composition of the tank effluents for the day, night and 24 hr. samples are shown in tables 24, 25 and 26.

TABLE 24.

MONTHLY AVERAGE ANALYSES OF EFFLUENT OF DORTMUND TANKS.

Date	Parts Per Million								Sampling Period	Period of Flow Hours
	Nitrogen as				Oxygen Consumed Total	Suspended Matter				
	Total Organic	Free Amm.	Nitrites	Nitrates		Total	Volatile	Fixed		
TANK D—DAY SAMPLES—SUNDAYS OMITTED.										
1913										
January	78	26	.56	1.92	228	320	238	82	11 A.M. to 2 A.M.	4.0
February	75	25	.61	2.16	229	265	194	71	12 M. to 2 A.M.	4.0
March	55	22	.45	1.84	174	243	176	67	2 P.M. to 4 A.M.	6.0
April	54	22	.14	1.07	148	190	148	42	2 P.M. to 4 A.M.	6.0
May	48	33	.08	.86	133	298	220	78	2 P.M. to 4 A.M.	6.0
June	36	42	.002	.58	122	210	160	50	2 P.M. to 4 A.M.	6.0
TANK C—DAY SAMPLES—SUNDAYS OMITTED.										
1913										
July	53	30	.21	.89	143	275	211	64	10 A.M. to 12 Mid.	2.0
August	59	30	.29	1.16	145	332	237	95	10 A.M. to 12 Mid.	1.9
September	58	25	.53	.87	154	234	187	47	10 A.M. to 12 Mid.	1.9
October	55	25	.45	1.51	175	208	152	56	10 A.M. to 12 Mid.	1.9
November	67	24	.51	2.28	186	242	186	56	10 A.M. to 12 Mid.	1.9
December	73	25	.41	3.80	182	255	198	57	10 A.M. to 12 Mid.	1.9

REDUCTION OF SUSPENDED MATTER. Table 25 shows the monthly average reduction in suspended matter for Tank C on the day, night and 24 hour samples. Similar results for Tank D are given in table 26. Th averages by periods of flow are given in table 27.

TABLE 25.

NEW DORTMUND TANK (TANK C). PLAIN SEDIMENTATION.

Reduction in Suspended Matter Based on Monthly Averages.

Date	Suspended Matter			Parts Per Million			Per Cent Reduction			Period of Flow Hr.	Mean Upward Vel. Ft. Per Hr.
	Influent*			Effluent							
	Total	Vol.	Fixed	Total	Vol.	Fixed	Total	Vol.	Fixed		
					DAY SEWAGE—SUNDAYS OMITTED						
1913											
July.....	543	420	123	275	211	64	49	50	48	2.0	1.8
Aug.....	654	406	148	332	237	95	40	42	36	1.9	2.3
Sept.....	577	440	137	234	187	47	59	58	66	1.9	2.3
Oct......	528	420	108	208	152	56	61	64	48	1.9	2.3
Nov......	556	437	119	242	186	56	57	57	53	1.9	2.3
Dec......	502	400	102	255	198	57	49	50	44	1.0	4.5
1914											
Feb. 9–28	484	395	89	141	108	33	71	73	63	4.0	1.1
Mar.....	464	380	84	141	125	16	70	67	81	4.0	1.1
Apr......	356	291	65	122	100	22	66	66	66	4.0	1.1
					NIGHT SEWAGE—SUNDAYS INCLUDED—1913						
1913											
July.....	148	92	56	154	107	47	4†	16†	16	2.0	1.8
Aug.....	142	95	47	97	67	30	32	30	36	1.9	2.3
Sept.....	153	110	43	77	63	14	50	43	67	1.9	2.3
Oct......	128	93	35	69	51	18	46	45	49	1.9	2.3
Nov......	148	107	41	83	58	25	44	46	39	1.9	2.3
Dec......	165	120	45	107	75	32	35	37	29	1.0	4.5
1914											
Feb. 9–28	79	59	20	67	53	14	15	10	30	4.0	1.1
Mar.....	89	66	23	62	46	6	42	30	74	4.0	1.1
Apr......	73	58	15	60	45	15	20	22	0	4.0	1.1
					DAY AND NIGHT (24 HOUR) SEWAGE—SUNDAYS OMITTED.						
1913											
July.....	389	297	92	224	168	55	42	43	40	2.0	1.8
Aug.....	407	296	111	241	173	68	41	42	39	1.9	2.3
Sept.....	411	316	95	173	140	33	58	56	65	1.9	2.3
Oct......	381	298	83	155	114	41	59	62	51	1.9	3.3
Nov......	401	313	88	184	140	44	54	55	50	1.9	2.3
Dec......	376	298	78	200	152	48	47	49	39	1.0	4.5
1914											
Feb. 9–28	332	268	64	113	88	25	66	67	61	4.0	1.1
Mar.....	323	262	61	109	96	13	66	63	79	4.0	1.1
Apr......	250	204	46	98	79	19	61	61	59	4.0	1.1

NOTE: † Denotes increase.
* Grit chamber effluent.

TABLE 26.

OLD DORTMUND TANK (TANK D). PLAIN SEDIMENTATION.

Reduction in Suspended Matter Based on Monthly Averages.

Date	Suspended Matter—Parts Per Million						Per Cent Reduction			Period of Flow Hr.	Mean upward Vel. Ft. Per Hr.
	Influent*			Effluent							
	Total	Vol.	Fixed	Total	Vol.	Fixed	Total	Vol.	Fixed		
	DAY SEWAGE—SUNDAYS OMITTED.										
1913											
Jan......	670	519	151	320	238	82	52	54	46	4.0	2.6
Feb......	605	455	150	265	194	71	56	57	53	4.0	2.6
Mar.....	626	484	142	243	176	67	61	64	53	6.0	1.7
Apr......	523	390	133	190	148	42	64	62	68	6.0	1.7
May.....	597	450	147	298	220	78	50	51	47	6.0	1.7
June.....	580	437	143	210	160	50	64	63	65	6.0	1.7
1914											
Jan. 5-Feb. 7.	505	410	95	103	83	20	80	80	79	10.0	1.0
	NIGHT SEWAGE—SUNDAYS INCLUDED.										
1913											
Jan......	204	147	57	145	105	40	29	29	23	4.0	2.6
Feb......	150	102	48	165	119	46	10†	17†	4	4.0	2.6
Mar.....	157	108	49	124	95	29	21	12	41	6.0	1.7
Apr......	125	79	46	102	70	32	18	11	30	6.0	1.7
May.....	185	122	63	209	156	53	13†	28†	16	6.0	1.7
June.....	156	103	53	158	116	42	1†	13†	21†	6.0	1.7
1914											
Jan. 5-Feb. 7	115	83	32	93	74	19	19	11	41	10.0	1.0
	DAY AND NIGHT (24 HOUR) SEWAGE—SUNDAYS OMITTED.										
1912											
Oct......	669	547	122	406	332	74	39	39	39	4.0	2.6
Nov.....	644	480	164	281	211	70	56	56	57	4.0	2.6
Dec......	524	410	114	260	200	60	50	51	47	4.0	2.6
1913											
Jan......	517	398	119	264	197	67	49	50	44	4.0	2.6
Feb......	446	332	114	236	169	67	47	49	41	4.0	2.6
Mar.....	456	347	109	200	146	54	56	58	50	6.0	1.7
Apr......	375	275	100	157	120	37	58	56	63	6.0	1.7
May.....	445	328	117	279	210	69	37	36	41	6.0	1.7
June.....	432	319	113	184	139	45	57	56	60	6.0	1.7
1914											
Jan. 5–Feb. 7	360	284	76	100	80	20	72	72	74	10.0	1.0

NOTE: † Denotes increase.
* Grit chamber effluent.

Table 27 indicates that both velocity of flow and the period of detention are important factors in determining the efficiency of this type of tank. With equal detention periods but varying velocities, the lower velocities give the higher removal of suspended matter. This has an important bearing on the economy of this type of tank, as the efficiency depends largely on the upward velocity, while the capacity is the product of the area and velocity. From the standpoint of economy, therefore, high velocities are desirable, but are obtained at the expense of efficiency.

TABLE 27.

REDUCTION IN SUSPENDED MATTER BY STATED PERIODS OF FLOW IN VERTICAL FLOW TANKS.

Tank	Detention Period Hours	Mean Upward Velocity Ft. per Hour	Susp. Matter—Parts per Mil. Influent Tot.	Influent Vol.	Influent Fix.	Effluent Tot.	Effluent Vol.	Effluent Fix.	Percent Reduction Tot.	Percent Reduction Vol.	Percent Reduction Fix.
					DAY SEWAGE						
D	10.0	1.0	505	410	95	103	83	20	80	80	79
C	4.0	1.1	435	355	80	135	111	24	69	69	70
C‡	3.0	1.5	416	...	...	115	...	..	72	..	..
D	6.0†	1.7	576	437	139	214	161	53	63	63	62
C	2.0	1.8	543	420	123	275	211	64	49	50	48
C	1.9	2.3	554	426	128	254	191	63	54	55	51
D	4.0	2.6	638	487	151	293	216	77	54	56	49
C	1.0	4.5	502	400	102	255	198	57	49	50	44
					NIGHT SEWAGE						
D	10.0	1.0	115	83	32	93	74	19	11	41	10
C	4.0	1.1	80	61	19	60	48	12	25	21	37
C‡	3.0	1.5	105	...	...	67	...	..	46	..	..
D	6.0†	1.7	146	97	49	128	94	34	12	3	31
C	2.0	1.8	148	92	56	154	107	47	4*	16*	16
C	1.9	2.3	143	101	42	82	60	22	43	41	48
D	4.0	2.6	177	125	52	155	112	43	12	11	17
C	1.0	4.5	165	120	45	107	75	32	35	37	29
					DAY AND NIGHT (24 Hour) SEWAGE						
D	10.0	1.0	360	284	76	100	80	20	72	72	74
C	4.0	1.1	302	245	57	107	88	19	65	64	67
C‡	3.0	1.5	3 00	...	...	99	...	..	67	..	..
D	6.0†	1.7	421	314	107	180	135	45	57	57	58
C	2.0	1.8	389	297	92	224	168	55	42	43	40
C	1.9	2.3	400	306	94	188	142	46	53	54	51
D	4.0	2.6	560	433	127	289	222	67	48	49	47
C	1.0	4.5	376	298	78	200	152	48	47	49	39

* Increase.
† One month omitted owing to development of extreme septic conditions.
‡ One month on screened sewage in daytime and one on raw sewage.

With velocities lower than 1.5 ft. per hr., a removal of about 70 per cent. of the suspended matter in the day sewage is obtained with careful operation. The reduction in suspended matter fluctuates considerably for the night flow, probably because the night sewage contains much less settling suspended matter. The reduction is always less than for the day sewage for the same reason, and also because the true period of flow is always less than the theoretical, resulting in the inclusion of some of the strong day sewage in the night effluent. The 24-hr. results, therefore, show somewhat lower efficiencies.

The results obtained for individual months vary. The results

obtained on Tank D in October, 1912, were somewhat poorer than for the remainder of the time during which the tank was run on the 4-hr. basis, due largely to the absence of the scum baffle. Likewise, the results for May, 1913, were considerably below the average for the 6-hr. period of flow, probably because of the long interval between cleanings at that time, combined with rising temperature of the sewage and the development of septic conditions causing unloading.

The results obtained from Tank C during the first two months of operation on a nominal period approximating 2 hr. were somewhat poorer than the average for the same period of flow. The effluents obtained in September and October, 1913, however, showed a great improvement, largely traceable to the installation of the scum baffle in July. The very frequent cleaning of this tank, preventing the establishment of septic conditions, also accounts for the quality of effluent obtained. During the months of May and July, 1914, Tank C was run on the effluent from the fine mesh rotary screen. The removal of suspended matter for the day samples is shown in tables 28 and 29. With a detention period of 3 hours, total removals of suspended matter averaging 68 and 78 per cent. were secured, of which 12 and 9 per cent. were taken out by the screen.

TABLE 28.

FINE SCREENING FOLLOWED BY PLAIN SEDIMENTATION IN DORTMUND TANK (TANK C).

Reduction in Suspended Matter Using Screened Sewage with Detention Period of 3.0 Hours and Upward Vel. 1.5 Ft. per Hr. Day Sewage in May, 1914.

Date May 1914	Total Suspended Matter Parts per Million			Per Cent Reduction Suspended Matter		
	Screen* Influent	Screen† Effluent	Tank† Effluent	Screen	Tank	Total
1	447	387	181	13	47	60
4	460	385	158	16	50	66
6	375	321	113	14	56	70
8	407	350	183	14	41	55
11	416	373	185	11	45	56
13	516	461	142	11	62	73
15	543	492	143	10	64	74
18	452	381	164	16	48	64
20	475	412	163	13	53	66
22	759	717	189	6	69	75
25	595	530	190	11	57	68
27	699	626	145	10	69	79
Average	512	453	163	12	56	68

Note—Individual samples cover 2 days, including date noted. Sundays omitted.
* Computed from effluent analyses and screenings.
† Corrected for dilution by wash water.

TABLE 29.

FINE SCREEN FOLLOWED BY PLAIN SEDIMENTATION IN DORTMUND TANK (TANK C).

Reduction in Suspended Matter Using Screened Sewage in Daytime with Detention Period of 3.0 Hours and Upward, Vel. of 1.5 Ft. per Hr.

Day July, 1914	Day Sewage						Night Sewage			Day and Night Sewage						Screenings P.P.M.
	Suspended Matter Parts per Mil.			Per Cent Reduction			Susp. Matter Parts per Mil.		Per Cent Reduction	Suspended Matter Parts per Mil.			Per Cent Reduction			
	Screen Infl. P	Screen Effl. F	Tank Effl. F	Screen	Tank	Total	Infl.	Effl.		Screen Infl.†	Screen Effl.†	Tank Effl.	Screen	Tank	Total	
6	527	475	105	10	70	80	102	38	63	368	335	80	9	69	78	52
8	349	306	93	12	61	73	100	16	84	256	229	64	11	64	75	46
10	374	340	91	9	67	76	52	76	46*	253	232	85	8	58	66	34
13	326	301	76	8	69	77	22	50	56	212	196	66	8	61	69	25
15	671	632	115	6	77	83	122	116	5	465	441	115	5	70	75	39
17	413	378	133	9	59	68	106	84	21	298	276	115	7	54	61	35
20	570	542	238	5	53	58	72	44	39	383	366	165	5	52	57	28
24	557	515	72	8	79	87	68	44	35	374	347	62	7	76	83	42
27	518	468	104	10	70	80	112	48	57	366	335	83	9	68	77	50
29	591	550	79	7	80	87	200	40	80	444	419	64	5	81	86	41
Avg..	497	451	111	9	69	78	96	56	42	342	318	90	7	67	74	39

NOTE:—* Denotes increase.
† Screen run from 8 a. m. to 11 p. m. only.
P Computed from effluent analyses and screenings.
F Corrected for dilution by wash water.
Individual samples cover 2 days, including date noted. Sundays omitted.

REDUCTION IN ORGANIC NITROGEN, FREE AMMONIA AND OXYGEN CONSUMED. Table 30 shows the reduction in organic nitrogen, free ammonia and oxygen consumed for the day sewage for both tanks. During the winter and early spring, the reduction in organic nitrogen and oxygen consumed was considerably less than in suspended matter, because of the presence of soluble wastes. The free ammonia showed a slight increase. With the return of warm weather, an increase in the percentage reduction of organic nitrogen and oxygen consumed approaching the removal obtained on suspended matter was noted. At the same time a marked increase in free ammonia was noted, as well as a decrease in nitrites and nitrates. Under the influence of rising temperature, oxidation of the organic matter in the sewage was apparently stimulated at the expense of the oxygen contained in the nitrites and nitrates, particularly in Tank D. The effect was not marked in Tank C, although a substantial reduction in oxygen consumed and organic nitrogen occurred, accompanied by a corresponding increase in free ammonia.

SLUDGE AND SCUM. Scum was consistently present on the surface of both tanks from the start, forming usually within 24 hr. after cleaning and often to a considerable thickness as time elapsed. During cold months it formed more slowly than in warm weather. Prior to the installation of scum boards, considerable scum escaped in the effluent, but thereafter much less.

During May and July, 1914, Tank C was run on the effluent from the rotary screen during the daytime with a detention period of three hours, and during June with the same detention period using the effluent from the grit chamber. A very slight scum accumulated during the last few days of the runs on screened sewage, but in June a heavy coating was present almost continually. The relative rates of scum formation of 0.5 cu. yds, per mil. gal. in May and 3.1 cu. yd. in June point to the value of preliminary fine screening as a possible remedy for excessive scum formation. The light fibrous material removed by the screen is largely responsible for the heavy mat of scum.

During the hot summer weather, the surface of the scum often baked hard in a thin skin, which, on removal, frequently revealed large colonies of maggots. The scum thus affords a very favorable breeding ground for flies, as well as the sludge drying on the sludge beds. Ordinarily the scum had no objectionable odor, except when stirred or agitated. Owing to the necessity of skimming off the

TABLE 30.

PLAIN SEDIMENTATION IN DORTMUND TANKS (TANKS C AND D).

Reduction in Organic Nitrogen, Free Ammonia and Oxygen Consumed in Day Sewage.

Date 1913	Parts per Million						Per Cent Reduction			Period of Flow Hours	Mean Upward Velocity Feet per Hr.
	Influent			Effluent							
	Organic Nitrogen	Free Ammonia	Oxygen Consumed	Organic Nitrogen	Free Ammonia	Oxygen Consumed	Organic Nitrogen	Free Ammonia	Oxygen Consumed		
TANK D											
January	96	24	322	78	26	228	19	8*	29	4.0	2.6
February	91	25	317	75	25	229	18	0	28	4.0	2.6
March	71	19	267	55	22	174	22	16*	35	6.0	1.7
April	70	20	250	54	22	148	23	10*	41	6.0	1.7
May	80	22	258	48	33	133	40	50*	48	6.0	1.7
June	81	21	264	36	42	122	56	100*	54	6.0	1.7
Average	82	22	280	58	28	167	29	27*	40	...	...
TANK C											
July	71	21	240	53	30	143	25	43*	40	2.0	1.8
August	74	22	228	59	30	145	20	36*	36	1.9	2.3
September	76	21	250	58	25	154	24	19*	38	1.9	2.3
October	69	22	251	55	25	175	20	19*	30	1.9	2.3
November	86	24	282	67	24	186	22	0	34	1.9	2.3
December	89	24	287	73	25	182	18	4*	37	1.0	4.5
Average	77	22	256	61	26	164	21	18*	36	...	...

* Denotes increase.

TABLE 31.

PLAIN SEDIMENTATION IN OLD DORTMUND TANK (TANK D).

Accumulation of Sludge and Scum in Cubic Yards per Million Gallons.

Date	Since Last Measurement			Since Last Cleaning			Since Start			Period of Flow Hours	Mean Upward Velocity Ft. per Hour	Remarks
	Sludge	Scum	Sludge and Scum	Sludge	Scum	Sludge and Scum	Sludge	Scum	Sludge and Scum			
1912												
Oct. 7...	2.8	...	...	2.8	...	...	2.7	...	...	4.0	2.6	Cleaned
25...	6.2	...	...	6.2	...	...	4.1	...	...	4.0	2.6	"
Nov. 9...	14.1	...	...	14.1	...	...	6.6	...	...	4.0	2.6	"
20...	...	1.0	...	...	1.0	...	...	1.0	...	4.0	2.6	Scum removed
22...	4.8	...	...	4.8	...	...	6.2	...	...	4.0	2.6	Cleaned
Dec. 4...	5.9	7.7	13.6	5.9	7.7	13.6	6.1	2.4	8.5	4.0	2.6	"
13...	14.0	...	...	14.0	...	...	7.1	...	...	4.0	2.6	"
24...	2.3	4.0	6.3	2.3	4.0	6.3	6.6	2.8	9.4	4.0	2.6	"
1913												
Jan. 11...	...	4.8	...	...	4.8	...	...	3.2	...	4.0	2.6	Scum removed
17...	8.9	9.2	18.1	8.9	9.2	18.1	7.1	3.5	10.6	4.0	2.6	Cleaned
Feb. 10...	4.2	1.8	6.0	4.2	1.8	6.0	6.6	3.2	9.8	4.0	2.6	"
22...	...	2.8	...	...	2.8	...	...	3.2	...	4.0	2.6	Scum removed
25...	13.7	3.6	17.3	13.7	3.6	17.3	7.3	3.2	10.5	4.0	2.6	Cleaned
Mar. 28...	...	2.9	...	...	2.9	...	...	3.1	...	6.0	1.7	Scum removed
Apr. 4...	8.1	13.0	21.1	8.1	13.0	21.1	7.4	3.4	10.8	6.0	1.7	Cleaned
May 7...	...	1.7	...	...	1.7	...	...	3.2	...	6.0	1.7	Scum removed
27...	1.9	...	...	1.9	...	...	6.5	...	...	6.0	1.7	Cleaned
June 11...	8.5	4.9	13.4	8.5	4.9	13.4	6.6	3.3	9.9	6.0	1.7	"
19...	...	6.7	...	...	6.7	...	...	3.4	...	6.0	1.7	Scum removed
July 1...	...	5.4	...	...	...	5.4	...	3.4	...	6.0	1.7	" "
7...	0.2	8.9	9.1	0.2	8.9	9.1	6.1	3.5	9.6	6.0	1.7	Cleaned

TABLE 32.

PLAIN SEDIMENTATION IN DORTMUND TANK (TANK C).

Accumulation of Sludge and Scum in Cubic Yards per Million Gallons.

Date	Since Last Measurement: Sludge	Since Last Measurement: Scum	Since Last Measurement: Sludge and Scum	Since Last Cleaning: Sludge	Since Last Cleaning: Scum	Since Last Cleaning: Sludge and Scum	Since Start: Sludge	Since Start: Scum	Since Start: Sludge and Scum	Period of Flow Hours	Mean Upward Velocity Ft. per Hour	Remarks
1913												
July 9	...	1.6	...	...	1.6	...	...	1.6	...	2.0	1.8	Cleaned
18	2.0	3.2	5.2	2.0	3.2	5.2	2.0	2.2	4.2	2.0	1.8	"
Aug. 2	1.5*	1.7	3.2	1.5*	1.7	3.2	1.8*	2.0	3.8	2.0	1.8	"
16	1.0	4.3	5.3	1.0	4.3	5.3	1.6	2.6	4.2	2.0	1.8	"
22	3.4	7.4	10.8	3.4	7.4	10.8	1.8	3.1	4.9	1.9	2.3	"
28	2.9	7.3	10.2	2.9	7.3	10.2	1.9	3.5	5.4	1.9	2.3	"
Sept. 5	2.1	3.9	6.0	2.1	3.9	6.0	1.9	3.6	5.5	1.9	2.3	"
12	3.2	4.9	8.1	3.2	4.9	8.1	2.0	3.7	5.7	1.9	2.3	"
22	2.1	4.7	6.8	2.1	4.7	6.8	2.0	3.8	5.8	1.9	2.3	"
26	7.8	7.6	15.4	7.8	7.6	15.4	2.3	4.0	6.3	1.9	2.3	"
Oct. 3	4.6	3.5	8.1	4.6	3.5	8.1	2.4	3.9	6.3	1.9	2.3	"
10	3.3	4.7	8.0	3.3	4.7	8.0	2.5	4.0	6.5	1.9	2.3	"
17	2.6	3.6	6.2	2.6	3.6	6.2	2.5	4.0	6.5	1.9	2.3	"
20	...	...	...	...	...	...	...	...	...	0.1 cu. yd. sludge removed		
23	...	...	...	...	...	...	...	...	...	0.19 " " "		
24	6.1	2.9	9.0	6.1	2.9	9.0	2.7	3.9	6.6	1.9	2.3	Cleaned
31	6.1	2.5	8.6	6.1	2.5	8.6	2.9	3.8	6.7	1.9	2.3	"
Nov. 7	7.3	2.5	9.8	7.3	2.5	9.8	3.1	3.8	6.9	1.9	2.3	"
21	2.8	2.9	5.7	2.8	2.9	5.7	3.1	3.7	6.8	1.9	2.3	"
Dec. 4	2.8	1.7	4.5	2.8	1.7	4.5	3.1	3.5	6.6	1.9	2.3	
16	2.7	1.9	4.6	2.7	1.9	4.6	3.0	3.3	6.3	1.0	4.5	
1914												
Jan. 5	1.6	1.9	3.5	1.6	1.9	3.5	2.8	3.0	5.8	1.0	4.5	"
Tank run on chemical precipitation basis Jan. 5 to Feb. 7 and measurements omitted.												
Feb. 18	5.7	0.0	5.7	5.7	0.0	5.7	2.8	...	...	4.0	1.1	
Mar. 4	6.4	0.0	6.4	6.1	0.0	0.1	2.9	...	...	4.0	1.1	Cleaned
5	36.2	...	...	36.2	...	...	3.0	...	...	4.0	1.1	
20	0.7	2.0	1.3	1.9	2.0	3.9	2.9	3.0	5.9	4.0	1.1	Cleaned
27	9.4	0.0	9.4	9.4	0.0	9.4	3.0	...	...	4.0	1.1	
Apr. 4	8.5	0.0	...	8.9	0.0	8.9	3.1	...	...	4.0	1.1	
9	1.2	0.0	...	6.2	0.0	6.2	3.0	...	...	4.0	1.1	Cleaned
16	9.0	...	...	9.0	...	...	3.1	...	...	4.0	1.1	
May 1	1.7	1.5	0.2	1.6	1.5	3.1	3.0	2.9	5.9	4.0	1.1	Cleaned
13	4.9	0.0	4.9	4.9	0.0	4.9	3.0	2.9	5.9	3.0	1.5	
26	5.0	0.0	5.0	5.0	0.0	5.0	3.1	2.9	6.0	3.0	1.5	
June 1	0.0	0.5	0.5	4.1	0.5	4.6	3.1	2.7	5.8	3.0	1.5	Cleaned
18	...	0.9	...	...	0.9	...	...	2.6	...	3.0	1.5	
19	4.1	34.6	...	4.1	34.6	...	3.1	2.7	5.8	3.0	1.5	

* Volums rsmoved uncertain.

scum frequently, this rapid accumulation involves considerable labor, and the high moisture content makes handling difficult.

Sludge was removed from Tank D at intervals of from 1 to 8 weeks, whereas cleanings of Tank C were made at approximately weekly intervals, owing to the relatively small volume of the sludge chamber (tables 31 and 32). The rate of accumulation of sludge and scum in Tank D fluctuated considerably between intervals of cleaning (table 31). The relative amounts of sludge and scum varied considerably. The average rate of accumulation of sludge and scum for different periods of flow is given in table 33.

TABLE 33.

SLUDGE ACCUMULATION BY PERIODS OF FLOW.

Tank	Detention Period Hours	Mean Upward Velocity Ft. per Hr.	Sludge Cu. Yd. per Mil. Gallons	Scum Cu. Yd. per Mil. Gallons	Total Cu. Yd. per Mil. Gallons	Remarks
C	1.9	2.3	3.1	3.5	6.6	
C	1.0	4.5	2.0	1.9	3.9	
C	4.0	1.1	3.9	2.0	5.9	
C	3.0	1.5	4.1	0.5	4.6	With screened sewage.
C	3.0	1.5	4.1	3.1	7.2	With Unscreened sewage.
D	4.0	2.6	7.3	3.2	10.5	
D	6.0	1.7	4.1	4.1	8.2	

The rate of accumulation varied between 8 and 10 cu. yd. of sludge and scum per million gallons for Tank D and between 4 and 7 cu. yd. for Tank C. Individual measurements show large fluctuations at different times due probably to the variable moisture content and the relative proportions of wet bottom sludge and comparatively dry top scum. The amount of suspended matter removed from the sewage at different seasons of the year would also tend to vary the rate of accumulation somewhat. Fine screening materially reduces the rate of scum accumulation. In deeper and larger tanks lower results might occur, as the sludge would compact somewhat. Septic conditions with resulting gas evolution also tend to keep the sludge stirred up and bring portions to the surface as scum. By far the greater portion of sludge was deposited during the day time, for, based on the analyses of the tank effluent, the retention of suspended matter during the nine night hours averaged less than 10 per cent. of the total amount deposited. The effect of variations in moisture content on the rate of scum accumulation is indicated in table 34, which shows the rate of accumulation for a short period for

TABLE 34.

PLAIN SEDIMENTATION IN DORTMUND TANK (TANK C).

Sludge and Scum Accumulation Based on Uniform Moisture Content.

Date	Cubic Yards Per Million Gallons								Per Cent Moisture		Detention Period Hours	Mean Upward Velocity Ft. per Hour	Remarks
	Between Measurements				Since Start								
	As Measured		90% Sludge	80% Scum	As Measured		90% Sludge	80% Scum					
1914	Sludge	Scum			Sludge	Scum			Sludge	Scum			
Apr. 9...	....	....	....	....	....	....	....	....	....	....	4.0	1.1	Start
16...	8.97	....	7.58	....	8.97	....	7.58	....	92.4	....	4.0	1.1	
May 1...	1.68	1.54	0.53	1.43	1.59	1.54	1.96	1.59	90.5*	81.7	4.0	1.1	*Before cleaning
1...	....	....	....	....	....	....	....	....	93.6*	....	...	...	*After "
13...	4.89	....	7.00	....	2.67	....	4.08	....	87.5	....	3.0	1.5	
26...	5.03	....	5.22	....	3.42	....	4.37	....	88.5	....	3.0	1.5	
June 1...	0.00	0.45	0.51	0.59	3.24	1.29	4.05	1.27	88.1*	76.6	...	...	*Before cleaning
1...	....	....	....	....	....	....	....	....	....*	....	3.0	1.5	*After "
18...	....	0.89	....	0.93	....	1.16	....	1.16	....	79.3	3.0	1.5	
19...	1.09	34.65	3.41	22.30	3.52	1.87	3.79	1.61	90.7	87.2	3.0	1.5	
19...	....	....	....	....	....	....	....	....	93.0	....	3.0	1.5	

† Not taken.

Tank C, with all results reduced to a standard moisture content. For comparison sludge measurements are also given.

The sludge flowing from the tanks varied in color from a dirty brownish or greenish gray to almost black, that from Tank D frequently giving off a strong odor of hydrogen sulphide. This was not noticed in Tank C, possibly because the small sludge storage space necessitated more frequent cleaning, thus minimizing the development of septic action. Considerable amounts of gas were given off during the winter by Tank D.

Some difficulty occurred in running the sludge from the tanks, particularly during the winter of 1912-1913, when on several occasions it became almost impossible to clean Tank D. After a small amount of sludge was withdrawn, clear sewage would break through. If shut down until the sludge gathered about the sludge pipe inlet,

TABLE 35.

PLAIN SEDIMENTATION IN OLD DORTMUND TANK (TANK D).

Analyses of Bottom Sludge and Top Scum.

Date	Specific Gravity	Per Cent Moisture	Calculated to Dry Weight—Percentage			
			Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble
			BOTTOM SLUDGE			
1912						
Oct. 7*	1.01*	98.9*	2.24	69	31	9.7
25*	1.00*	91.8*	2.64	80	20	7.8
Nov. 9*	1.00*	95.8*	2.32	70	30	8.6
22*	1.03*	92.1*	3.04	77	23	8.8
Dec. 4	1.02	93.1	3.44	78	22	10.0
13	1.02	94.6	4.90	78	22	7.3
24	1.02	90.8	3.36	79	21	9.5
1913						
Jan. 17	1.03	89.7	3.36	76	24	8.0
Feb. 10	1.03	91.6	1.68	76	24	9.8
25	1.00*	89.1	3.04	78	22	9.3
Apr. 4	1.00*	92.0	2.56	74	26	7.7
May 27	1.03	....	2.56	74	26	8.8
June 11	1.02	92.8	2.32	75	25	6.4
Average	1.02	91.7	2.88	76	24	8.6
			TOP SCUM			
1912						
Oct. 25	1.02	93.0	....	75	25	....
Nov. 22	1.01	81.3	3.36	74	26	10.4
Dec. 3	1.02	85.0	3.84	78	22	9.0
24	1.02	84.7	3.52	72	28	9.7
1913						
Jan. 17	....	87.2	....	..	..	....
Feb. 10	1.03	87.7	1.44	77	23	11.6
25	1.01	90.1	2.16	75	25	9.2
Mar. 27	1.02	84.3	2.64	76	24	8.6
Apr. 4	1.02	81.9	1.76	74	26	7.4
May 7	1.05	79.6	2.64	75	25	11.4
22	1.03	80.6	2.96	75	25	7.8
June 11	1.02	81.0	2.16	73	27	7.2
19	1.01	81.0	2.16	73	27	9.2
Average	1.02	84.5	2.60	75	25	9.1

Note: * Samples from sludge filter omitted from average. Other sludge samples from tank.

flow would again resume. Twice this difficulty was overcome by suspending a metal disc about three feet in diameter over the surface of the sludge, which may have prevented vortex action. Differences in the character of the sludge may have caused the variations noted. However, sludge was readily removed when the disc was used. The low specific gravity of the sludge, combined with the stirring and uplifting tendency of the gas formed, may have prevented free flow toward the sludge outlet, or the friction against the sides of the tank and hopper may have caused the sludge to hang, forming a cone-shaped depression in the center of the sludge mass through which the overlying sewage finally broke. Stirring was effective when the sludge had become particularly compact.

Analyses of sludge and scum for Tank D (table 35) and for Tank C (table 36) show the composition of the sludges and scums

TABLE 36.

PLAIN SEDIMENTATION IN DORTMUND TANK (TANK C).

Analyses of Bottom Sludge and Top Scum.

Date	Specific Gravity	Per Cent Moisture	Calculated to Dry Weight—Percentage			
			Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble
			BOTTOM SLUDGE			
1913						
July 18	1.02	89.5	2.56	69	31	7.1
Aug. 2	1.02	92.7	2.80	74	26	6.2
16	1.02	91.3	2.44	69	31	7.9
22	1.05	86.8	1.84	62	38	5.5
28	....	92.5	2.72	77	23	3.3
Sept. 22	1.02	89.9	2.56	67	33	7.6
Oct. 3	1.01	91.3	2.56	71	29	9.0
17	1.02	91.2	2.96	73	27	7.9
Nov. 7	1.01	90.2	2.88	81	19	9.1
21	1.02	90.0	2.88	78	22	8.2
Dec. 16	1.02	87.2	3.04	71	29	7.3
1914						
Jan. 5	1.02	91.0	....	73	27	....
Mar. 20	1.03	92.5	2.56	67	32	10.8
27	1.01	91.7	....	..	..	17.4 top of sludge
27	1.01	94.2	....	..	..	13.5 bottom of sludge
Average	1.02	90.6	2.65	72	28	8.1
			TOP SCUM			
1913						
July 9	1.02	81.2	2.56	72	28	7.4
18	1.01	79.8	2.64	70	30	7.7
Aug. 2	1.01	84.4	2.88	62	38	7.2
16	0.99	84.4	2.40	69	31	6.9
22	1.01	82.6	2.56	68	32	7.3
28	1.01	83.6	3.12	71	29	3.5
Sept. 22	1.05	83.6	2.56	68	32	7.5
Oct. 3	1.02	83.5	3.04	72	28	9.2
17	1.02	83.7	3.04	71	29	9.4
Nov. 7	1.02	86.3	2.64	76	24	8.3
21	1.03	83.4	3.04	77	23	7.6
1914						
Mar. 20	1.03	84.4	2.88	..	..	10.5
Average	1.02	84.5	2.78	70	30	7.7

to be almost identical, except for the lower moisture content of the scums averaging 84 per cent. as compared with 92 per cent. for sludge in Tank D and 85 per cent. against 91 per cent. for Tank C. The percentage of volatile matter in the sludge and scum from both tanks is high, little difference being noted between the sludge and scum from the same tank. The nitrogen content averages nearly 3 per cent., whereas the ether soluble material averages 8 to 8.5 per cent. The fat content of the sludges was determined by extracting with ether without acidifying. When the sample is first acidified, considerably higher results are obtained, probably due to the breaking down or "cracking" of the soap fats which are not recorded by the simple ether extract. For instance, 2 samples of bottom sludge, showing percentages of 7.4 and 10.0 with simple ether extraction, gave values of 10.0 and 25.6 when first acidified.

ACTUAL PERIOD OF FLOW. In the body of this report, all figures have been based on the nominal period of flow, assuming complete and uniform displacement, a condition only approximated in practice. Several attempts were made to measure the actual deten-

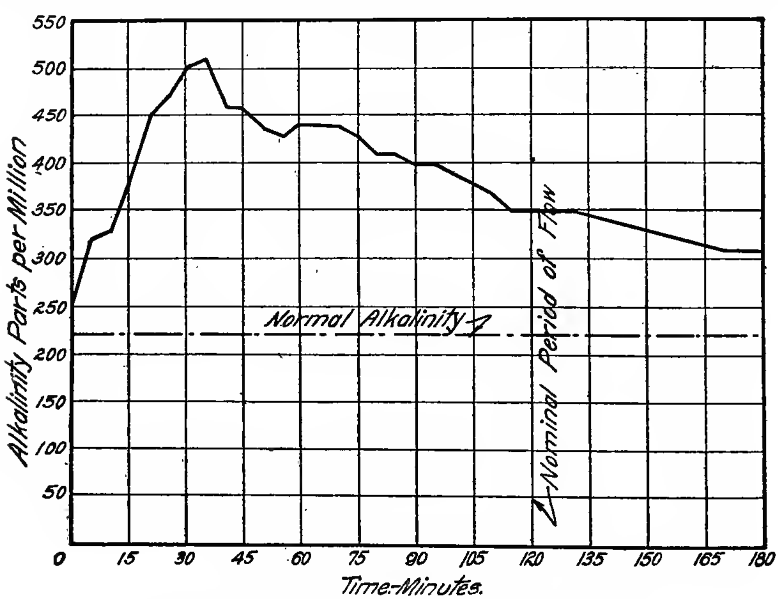


Fig. 12. Flow Period in Dortmund Tank (C).

tion period but the unusual character of the sewage interfered. Dyes were tried with indifferent success, owing to the reducing action of the sewage on the coloring matter and the difficulty of getting a distinct trace of color in the highly colored effluent. Of the chem-

icals ordinarily used, the quantity required to produce an appreciable effect was so large as to be impracticable in most cases.

A fairly successful test of Tank C was, however, made while running on a two-hour schedule, before the conical distributor was added to the influent pipe. The alkalinity of the sewage was increased on a Sunday by adding sodium carbonate, samples being taken at 5-min. intervals for 2 hr. and every 10 min. thereafter for an additional hour. The results (Fig. 12) indicate considerable variation in rate of flow, a portion of the sewage passing through very rapidly, the peak in the curve being reached 35 min. after application began. A portion flows through very slowly, the alkalinity being high at the end of 3 hr. Diffusion of the chemical may have had an influence. Although sampling was not continued until normal alkalinity was restored, an average period of flow was found less than the theoretical.

CHAPTER VIII.

EMSCHER TANK.

GENERAL. The distinguishing feature of the Imhoff or Emscher tank (tank E) is the provision made for the retention and digestion of the sludge in a chamber separate from that through which the sewage flows, so arranged that the gases of digestion pass off through a separate vent without contact with the incoming sewage. The construction and details of the original and remodeled tanks have already been outlined. (Fig. 8.) The operating schedule is shown in table 37.

TABLE 37.

OPERATING SCHEDULE OF EMSCHER TANK (TANK E).

Date		Rate Gal. Daily	Period of Flow Hrs.	Velocity			
				Ft. per Hr.		Mm. per Sec.	
From	To			Down	Up	Down	Up
VERTICAL RADIAL FLOW, ORIGINAL							
Sept. 16, 1912	Nov. 2, 1912	27,400	2.0	8.7	3.8	0.74	0.32
Nov. 2, 1912	Mar. 1, 1913	18,200	3.0	5.8	2.5	0.49	0.21
Mar. 1, 1913	May 15, 1913	13,700	4.0	4.4	1.9	0.37	0.16
May 15, 1913	Oct. 1, 1913	27,400	2.0	8.7	3.8	0.74	0.32
Oct. 1, 1913	Feb. 10, 1914	36,400	1.5	11.6	5.0	0.99	0.44
Feb. 10, 1914	Mar. 9, 1914	27,400	2.0	8.7	3.8	0.74	0.32
HORIZONTAL FLOW, REMODELLED							
Mar. 19, 1914	June 1, 1914	15,200	1.9	9.2*	...	0.79*	....
June 1, 1914	Sept. 2, 1914	10,000	2.9	6.0*	...	0.52*	....

* Horizontal velocity.

ANALYTICAL RESULTS. Monthly averages showing the character of the effluent are given in tables 38, 40 and 41.

TABLE 38.

AVERAGE ANALYSES OF EFFLUENT FROM EMSCHER TANK (TANK E).

Date	Parts Per Million								Sampling Period	Period of Flow Hours
	Nitrogen as				Oxygen Consumed	Suspended Matter				
	Total Organic	Free Amm.	Nitrites	Nitrates		Total	Volatile	Fixed		
DAY SAMPLES—SUNDAYS OMITTED.										
1913										
January	79	30	.25	2.33	238	331	253	78	10 A.M. to 1 A.M.	3.0
February	79	28	.25	2.33	237	300	233	67	11 A.M. to 1 A.M.	3.0
March	57	24	.25	2.45	198	269	200	69	10 A.M. to 12 Mid.	4.0
April	55	26	.17	1.70	180	291	227	64	10 A.M. to 12 Mid.	4.0
May 1 to 15	50	40	.00	1.10	147	292	215	77	10 A.M. to 12 Mid.	4.0
16 to 31	66	33	.14	1.77	150	279	211	68	10 A.M. to 12 Mid.	2.0
June	55	40	.19	1.07	155	272	205	67	10 A.M. to 12 Mid.	2.0
July	50	36	.23	.93	132	267	197	70	10 A.M. to 12 Mid.	2.0
August	45	42	.15	.77	118	284	200	84	10 A.M. to 12 Mid.	2.0
September	50	37	.26	1.02	149	328	246	82	9:30 A.M. to 11:30 P.M.	1.5
October	48	32	.32	1.68	171	248	184	64	9:30 A.M. to 11:30 P.M.	1.5
November	60	30	.44	2.64	203	262	205	57	9:30 A.M. to 11:30 P.M.	1.5
December	82	30	.28	1.61	185	275	218	57	9:30 A.M. to 11:30 P.M.	1.5
Avg. 1913	60	30	.24	1.66	177	284	215	69		
1914										
January	70	27	.24	2.7	...	227	179	48	9:30 A.M. to 11:30 P.M.	1.5

TABLE 39.

SEDIMENTATION IN EMSCHER TANK (TANK E).

Reduction in Suspended Matter Based on Monthly Averages. Day Samples. Sundays not Included.

Date	Suspended Matter—Parts per Million						Per Cent Reduction			Period of Flow Hours	Mean Upward Velocity Ft. per Hour
	Influent*			Effluent							
	Total	Volatile	Fixed	Total	Volatile	Fixed	Total	Volatile	Fixed		
1913											
January	670	519	151	331	253	78	51	51	48	3.0	2.5
February	605	455	150	300	233	67	50	49	55	3.0	2.5
March	626	484	142	269	200	69	57	59	51	4.0	1.9
April	523	390	133	291	227	64	44	42	52	4.0	1.9
May 1 to 15	623	475	148	292	215	77	53	55	48	4.0	1.9
16 to 31	574	428	146	279	211	68	51	51	53	2.0	3.8
June	580	437	143	272	205	67	53	53	53	2.0	3.8
July	543	420	123	267	197	70	51	53	43	2.0	3.8
August	554	406	148	284	200	84	49	51	43	2.0	3.8
September	577	440	137	328	246	82	43	44	40	2.0	3.8
October	528	420	108	248	184	64	53	56	41	1.5	5.0
November	556	437	119	262	205	57	53	53	52	1.5	5.0
December	502	400	102	247	199	48	51	50	53	1.5	5.0
1914											
January	498	411	87	227	179	48	54	57	45	1.5	5.0
Feb. 9 to 28	467	401	66	185	148	37	60	61	44	2.0	3.8
Mar. 1 to 9	423	337	86	161	133	28	62	61	67	2.0	3.8
Tank Remodeled Mar. 9 to 18 (Velocities Horizontal).											
Mar. 20 to 31	553	461	92	225	194	30	59	58	67	1.9	9.2
April	356	291	65	137	111	26	62	62	60	1.9	9.2
May	395	...	...	156	...	..	61	..	..	1.9	9.2
June	381	...	...	112	...	..	71	..	..	2.9	6.0
July	363	...	...	107	...	..	71	..	..	2.9	6.0
August	350	...	...	83	...	..	76	..	..	2.9	6.0

* Grit chamber effluent.

TABLE 40.

SEDIMENTATION IN EMSCHER TANK (TANK E).

Reduction in Suspended Matter Based on Monthly Averages. Night Samples. Sundays Included.

Date	Suspended Matter—Parts per Million						Per Cent Reduction			Period of Flow Hours	Mean Upward Velocity Ft. per Hour
	Influent*			Effluent							
	Total	Volatile	Fixed	Total	Volatile	Fixed	Total	Volatile	Fixed		
1913											
January	204	147	57	189	135	54	7	8	5	3.0	2.5
February	150	102	48	159	111	48	9†	8†	0	3.0	2.5
March	157	108	49	136	101	35	13	6	29	4.0	1.9
April	125	79	46	156	116	40	25†	47†	13	4.0	1.9
May 1 to 15	204	130	74	178	113	65	13	13	12	4.0	1.9
16 to 31	169	115	54	169	118	51	0	3	6	2.0	3.8
June	156	103	53	138	96	45	12	7	21	2.0	3.8
July	134	89	45	97	65	32	28	27	29	2.0	3.8
August	136	92	44	94	60	34	31	35	31	2.0	3.8
September	156	117	39	90	79	11	42	32	73	2.0	3.8
October	130	92	38	87	65	22	32	29	42	1.5	5.0
November	133	99	34	102	73	29	23	26	15	1.5	5.0
December	160	119	41	79	54	25	51	55	39	1.5	5.0
1914											
January	115	84	31	85	57	28	26	32	10	1.5	5.0
Feb. 9 to 29	85	65	20	60	45	15	29	31	25	2.0	3.8
Mar. 1 to 9	83	54	29	82	60	22	1	11†	24	2.0	3.8
Tank Remodeled March 9 to 18 (Velocities Horizontal).											
Mar. 20 to 31	113	86	27	94	77	17	17	10	37	1.9	9.2
April	73	58	15	51	38	13	30	34	13	1.9	9.2
May	87	...	..	58	...	..	33	..	..	1.9	9.2
June	114	...	..	57	...	..	50	..	..	2.9	6.0
July	93	...	..	53	...	..	43	..	..	2.9	6.0
August	92	...	..	43	...	..	53	..	..	2.9	6.0

* Grit chamber effluent.
† Denotes increase.

TABLE 41.

SEDIMENTATION IN EMSCHER TANK (TANK E).

Reduction in Suspended Matter Based on Monthly Averages. Day and Night (24 Hour) Samples. Sundays not Included.

Date	Suspended Matter—Parts per Million						Per Cent Reduction			Period of Flow Hours	Mean Upward Velocity Ft. per Hour
	Influent*			Effluent							
	Total	Volatile	Fixed	Total	Volatile	Fixed	Total	Volatile	Fixed		
1912											
October	669	547	122	341	289	52	49	52	57	2.0	3.8
November	644	480	164	337	252	85	48	48	48	3.0	2.5
December	524	410	114	275	218	57	48	47	50	3.0	2.5
1913											
January	517	398	119	281	212	69	46	47	42	3.0	2.5
February	446	332	114	248	188	60	44	43	47	3.0	2.5
March	456	347	109	220	165	55	52	52	50	4.0	1.9
April	375	275	100	242	188	54	36	31	46	4.0	1.9
May 1 to 15	473	350	123	251	182	69	47	48	44	4.0	1.9
16 to 31	420	309	111	241	176	65	43	43	41	2.0	3.8
June	432	319	113	229	170	59	49	47	48	2.0	3.8
July	389	297	92	200	146	54	49	51	41	2.0	3.8
August	407	296	111	216	151	65	47	49	41	2.0	3.8
September	411	316	95	244	184	60	41	42	37	2.0	3.8
October	381	298	83	196	151	45	49	50	44	1.5	5.0
November	401	313	88	204	158	46	49	50	48	1.5	5.0
December	376	298	78	186	146	40	51	51	49	1.5	5.0
1914											
January	357	287	70	177	137	40	50	52	43	1.5	5.0
Feb. 9 to 28	326	271	55	138	109	29	58	60	47	2.0	3.8
Mar. 1 to 9	296	231	65	132	106	26	55	54	60	2.0	3.8
Tank Remodeled Mar. 9 to 18 (Velocities Horizontal).											
Mar. 20 to 31	399	329	70	183	161	22	54	51	69	1.9	9.2
April	250	204	46	104	83	21	58	59	54	1.9	9.2
May	301	...	...	125	...	..	58	..	..	1.9	9.2
June	282	...	...	92	...	..	67	..	..	2.9	6.0
July	262	...	...	87	...	..	67	..	..	2.9	6.0
August	253	...	...	68	...	..	73	..	..	2.9	6.0

* Grit chamber effluent.

REDUCTION OF SUSPENDED MATTER. Tables 39, 40 and 41 show the percentage reduction in suspended matter for the day, night, and 24-hr. samples by months. In the day and 24-hr. averages Sunday results have been excluded, owing to the greatly decreased strength of the sewage. The average results by periods of flow are given in table 42.

TABLE 42.

REDUCTION IN SUSPENDED MATTER BY PERIODS OF FLOW.

Detention Period Hours	Mean Upward Velocity Ft. per Hours	Suspended Matter—Parts per Million						Per Cent Reduction		
		Influent			Effluent					
		Total	Vol.	Fixed	Total	Vol.	Fixed	Total	Vol.	Fixed
				DAY SEWAGE						
4.0	1.9	586	446	140	283	214	69	52	52	51
3.0	2.5	638	487	151	316	243	73	50	50	52
2.0	3.8	545	418	127	267	199	68	51	52	47
1.5	5.0	521	417	104	246	192	54	53	54	48
				Horizontal Flow						
1.9	9.2†	400	...	...	158	...	..	61	..	..
2.9	6.0†	365	...	...	101	...	..	72	..	..
				NIGHT SEWAGE						
4.0	1.9	154	125	52	174	123	51	2	2	2
3.0	2.5	177	101	53	153	110	43	1	9*	19
2.0	3.8	137	95	42	104	74	30	24	22	28
1.5	5.0	135	99	36	88	62	26	35	39	28
				Horizontal Flow						
1.9	9.2†	85	...	...	60	...	..	29	..	..
2.9	6.0†	100	...	...	51	...	..	49	...	..
				24 HOUR SEWAGE						
4.0	1.9	427	319	108	235	177	58	45	45	46
3.0	2.5	533	405	128	285	217	68	47	47	47
2.0	3.8	435	336	92	228	174	54	48	48	45
1.5	5.0	379	299	80	191	148	43	50	51	46
				Horizontal Flow						
1.9	9.2†	293	...	...	124	...	..	58	..	..
2.9	6.0†	266	...	...	82	...	..	69	..	..

* Denotes increase.
† Horizontal velocity.

The efficiency of the Emscher tank with different vertical velocities, during the operation of the tank on the radial flow basis, varied much less than did that of the Dortmund tanks. During the entire period of operation on the 3-hr. and 4-hr. periods, the process of ripening was going on in the digestion chamber, causing more or less disturbance in the operation of the tank. Scum baffles for the

effluent nipples were not installed then or during the greater part of the period during which the tank was operating on a 2-hr. detention period. During September, 1913, the sludge level rose above the level of the slots. When the period was changed to a 1½-hr. basis, individual scum baffles were provided for the effluent nipples, retaining considerable light scum which formed on the surface of the settling chamber. With the change to horizontal flow, considerably higher efficiencies were recorded.

REDUCTION OF ORGANIC NITROGEN, FREE AMMONIA AND OXYGEN CONSUMED. Table 43 shows the reduction in organic nitrogen, free ammonia and oxygen consumed for the day sewage, for 1913. The decrease in organic nitrogen, while appreciable, was considerably less than in suspended matter, because of the large amount of organic matter present in solution. The free ammonia consistently increased, accompanied by a decrease in nitrites and nitrates, indicating a slight oxidation of the organic nitrogenous

TABLE 43.

SEDIMENTATION IN EMSCHER TANK (TANK E).

Reduction in Organic Nitrogen, Free Ammonia and Oxygen Consumed in Day Sewage

Date 1913	Parts per Million.						Per Cent Reduction			Period of Flow Hr.
	Influent†			Effluent						
	Org. Nit.	Free Amm.	Oxy. Cons.	Org. Nit.	Free Amm.	Oxy. Cons.	Org. Nit.	Free Amm.	Oxy. Cons.	
Jan.	96	24	322	79	30	238	18	25*	26	3.0
Feb.	91	25	317	79	28	237	13	12*	25	3.0
Mar.	71	19	267	57	24	198	20	26*	26	4.0
Apr.	70	20	250	55	26	180	21	30*	28	4.0
May 1 to 15	83	23	268	50	40	147	40	74*	45	4.0
16 to 31	78	21	250	56	33	150	28	57*	40	2.0
June	81	21	264	55	40	155	32	91*	41	2.0
July	71	21	240	53	30	143	25	43*	40	2.0
Aug.	74	22	228	45	42	118	41	104*	48	2.0
Sept.	76	21	250	50	37	149	34	76*	40	2.0
Oct.	69	22	251	48	32	171	30	45*	32	1.5
Nov.	86	24	282	60	30	203	30	25*	28	1.5
Dec.	89	24	287	72	32	185	19	33*	36	1.5
Av.	80	24	268	59	32	178	26	33*	34	...

* Denotes increase.
† Crude sewage.

matter. With the approach of warm weather in May, a sharp increase in the reduction of organic nitrogen was noted, together with an increase in the amount of free ammonia. The nitrites and nitrates were also lower. These changes occurred almost simultaneously,

apparently following increasing temperature, with the resultant increase in bacterial action and increased oxidation of organic wastes. The oxygen consumed was decreased less than for the suspended matter, owing to the presence of soluble organic matter, altho in the late spring and summer the percentage reduction approached that obtained on the suspended matter. Apparently the same factors influencing the reduction of organic nitrogen were at work here also.

SLUDGE CHAMBER. The Emscher tank is about 17 ft. deep from the flow line to the bottom of the hopper. Seven days after the tank was started, the evolution of gas became noticeable and the gas funnel had plugged to a depth of about 5 ft. with a brownish floating sludge or scum of very offensive odor. This scum was broken up daily to liberate the accumulation of gas underneath, and was frequently removed throughout the entire winter, and even up to the middle of April, 1913, as it formed quickly. At one time the accumulation reached a depth of 8 ft. The production of gas was practically continuous from the start, but the clogging of the gas vent, by the vigorous scum production, retarded the escape of gas at times and occasionally caused ebullition through the sludge ports. On one occasion, the pressure was so great beneath the plug of scum that an attempt to break it up caused the gas vent to overflow into the settling compartment. Odors at times were very noticeable, particularly of hydrogen sulphide.

After the first of May, 1913, however, little or no trouble was experienced, the ripening of the tank having apparently been completed. Only a thin mat of light floating material collected during the summer of 1913, altho ebullition of gas was continuous and vigorous. The odor of H_2S was noted occasionally, although usually only on very close examination. Slight white deposits, presumably sulphur, were noted about the effluent pipes. During the summer a thin greasy scum accumulated in the inlet portion of the settling chamber, but this seldom exceeded a depth of one inch and gave no trouble in operating the tank. With the approach of cold weather, the scum reappeared in the gas funnel, though not to the extent noted during the first few months of operation. With the remodelling of the tank scum has continued to accumulate in the gas vents to a small extent.

Owing to the excessive attention required to keep the gas vent clear during the first few months of operation, this tank was not regarded as favorably at first as the Dortmund tank. But as the tank became thoroughly ripened, the difficulties of operation largely

ceased, and very favorable results were obtained. The excessive scum formation is apparently incidental to the ripening of the tank, although occurring less markedly at other times. Ample area must be provided in the gas vents for the escape of the gases of digestion, far more than for domestic sewage. The original proportion was 8.8 per cent. and as remodeled 34.

TABLE 44.

SEDIMENTATION IN EMSCHER TANK (TANK E).

Sludge and Scum Accumulation in Cubic Yards Per Million Gallons.

Date	Cubic Yards Per Million Gallons					Detention Period Hours	Mean Upward Vel. ft. per hr	Cu. Yds. Sludge Removed
	Sludge Since Last Measurement	Scum Since Last Cleaning	Since Start					
			Sludge	Scum	Sludge and Scum			
1912								
Oct. 25	13.3	...	13.3	...	...	2.0	3.8	...
Nov. 7	....	3.3	....	3.3	...	3.0	2.5	...
16	....	16.0	....	5.0	...	3.0	2.5	...
22	13.4	....	3.4	...	...	3.0	2.5	...
Dec. 12	10.3	3.6	5.0	4.6	9.6	3.0	2.5	...
1913								
Jan. 11	....	2.9	...	4.2	...	3.0	2.5	...
Feb. 11	4.3	...	1.1	...	...	3.0	2.5	...
22	...	1.6	...	3.5	...	3.0	2.5	...
Apr. 4	...	1.4	...	3.1	...	4.0	1.9	...
18	...	5.2	...	3.2	...	4.0	1.9	...
23	8.8	...	3.2	...	...	4.0	1.9	3.3
June 11	6.3	0.1	3.9	2.6	6.5	2.0	3.8	...
24	0.6	0.0	3.6	...	...	2.0	3.8	2.3
18	4.3	0.0	3.7	...	...	2.0	3.8	4.5
Aug. 19	4.3	0.0	3.8	...	...	2.0	3.8	...
Sept. 5	8.5	0.0	4.1	...	...	2.0	3.8	3.3
27	...	...	...	...	...	2.0	3.8	0.2
30	9.3	0.1	4.6	...	...	2.0	3.8	4.9
Oct. 14	8.8	0.4	4.8	1.6	6.4	1.5	5.0	6.1
21	7.9	...	4.9	1.5	6.4	1.5	5.0	2.8
Nov. 6	11.2*	0.6	5.3	1.4	6.7	1.5	5.0	9.6*
13	....	0.4	...	1.4	...	1.5	5.0	...
18	....	5.0	...	1.5	...	1.5	5.0	...
20	17.4	1.0	5.9	...	...	1.5	5.0	...
26	3.2	...	5.9	1.5	7.4	1.5	5.0	4.7*
Dec. 10	...	0.4	...	1.5	...	1.5	5.0	...
12	13.8*	...	6.3	...	...	1.5	5.0	10.6*
17	8.9*	...	6.3	...	...	1.5	5.0	....
1914								
Jan. 12	....	0.4	...	1.3	...	1.5	5.0	....
16	...	3.5	...	1.3	...	1.5	5.0	....
19	7.0	2.8	6.4	1.3	7.7	1.5	5.0	10.1
21	0.0	1.4	6.4	1.3	7.7	1.5	5.0	....
28	7.6	0.4	6.4	1.3	7.7	1.5	5.0	....
Feb. 6	13.4	...	6.6	...	...	2.0	3.8	....
11	26.6	...	6.3	...	...	2.0	3.8	....
19	12.7	1.0	6.4	1.3	7.7	2.0	3.8	....
28	7.9	...	6.4	...	...	2.0	3.8	....
Mar. 9	14.5	1.1	6.5	1.1	7.6	2.0	3.8	17.7
March 9 to 18 Tank Remodeled (Velocities Horizontal Hereafter)								
Mar. 20	7.7	38.5	6.5	1.4	7.9	1.9	9.2	....
27	13.8	....	6.6	...	...	1.9	9.2	....
Apr. 4	10.9	....	6.6	...	...	1.9	9.2	....
13	6.8	0.6	6.6	1.4	8.0	1.9	9.2	6.2
16	65.8	...	6.8	...	...	1.9	9.2	...
May 1	8.5	...	6.8	...	...	1.9	9.2	...
13	6.4	...	6.8	...	...	1.9	9.2	...
26	6.2	...	6.8	...	...	1.9	9.2	...
June 1	3.9	0.4	6.8	1.3	8.1	1.9	9.2	...

* Measuremen uncertain.

SLUDGE. Measurements of the sludge were made at monthly intervals, as a rule. The results expressed in cubic yards per million gallons are shown in table 44, with the quantities of scum from the gas funnel. The first few measurements of sludge fluctuated considerably, for on one or two occasions the sludge line was rather indefinite. Later measurements proved more consistent, the sludge apparently compacting with the ripening of the tank.

The rate of accumulation during the first few months of operation was very erratic. Sometimes very high rates occurred between individual measurements, and again an actual decrease, due probably to variations in density and compactness. The results are also somewhat obscured by the varying amounts of gas-lifted scum of lower moisture content and therefore smaller volume per unit of dry matter. After the disappearance of the scum, the results proved more uniform.

TABLE 45.

SLUDGE ACCUMULATION BY PERIODS.

Period		Detention Period Hours	Mean Upward Velocity Ft. per Hour	Cubic Yards per Mil. Gallons		
From	To			Sludge	Scum	Total
Sept. 16, 1912	Oct. 25, 1912	2.0	3.8	13.3	3.3	16.6
Oct. 25, 1912	Feb. 11, 1913	3.0	2.5	-3.8	3.6	-0.2
Feb. 11, 1913	Apr. 23, 1913	4.0	1.9	8.8	2.4	11.2
Apr. 23, 1913	Sept. 30, 1913	2.0	3.8	5.8	0.1	5.9
Sept. 30, 1913	Jan. 28, 1914	1.5	5.0	9.7	0.8	10.5
Jan. 28, 1914	Mar. 9, 1914	2.0	3.8	7.5	1.0	8.5
Horizontal Flow						
Mar. 9, 1914	June 1, 1914	1.9	9.2*	10.0	1.4	11.4

* Horizontal velocity.

The rates of sludge accumulation (table 44) show a reduction in the rate of scum formation after the ripening of the sludge chamber. Variations in volume may be largely traced to changes in moisture content and compactness of the sludge (table 46) when the rate of accumulation is reduced to a uniform moisture content. Possibly with a tank of working depth, a more compact sludge would be obtained, reducing the unit rate of accumulation. In applying the results to actual conditions, it should be noted that this tank was operated at a uniform rate of flow throughout the entire 24 hr., whereas, the flow in the sewer fluctuates between wide limits during the day and is greatest when the sewage is strongest and deposition is most rapid. Design must therefore take account

TABLE 46.

EMSCHER TANK (TANK E).

Showing Sludge Accumulation Based on Uniform Moisture Content.

Date	Cubic Yards Per Million Gallons								Per Cent Moisture		Deten. Period Hrs.	Mean Vel. Ft. Per Hr.	
	Between Measurements				Since Start								
	As Measured		90 p. c.	80 p. c.	As Measured		90 p. c.	80 p. c.					
	Sludge	Scum	Sludge	Scum	Sludge	Scum	Sludge	Scum	Sludge	Scum			
1914													
Apr. 13	....	...	....	...	....	...	....	...	....	....	...	...	Cleaned
16	65.8	...	32.0	...	65.8	...	32.0	...	95.1	....	1.9	9.2	
May 1	8.5	...	5.3	...	17.5	...	10.8	...	93.8	....	1.9	9.2	
13	6.4	...	3.8	...	13.0	...	7.7	...	94.1	....	1.9	9.2	
26	6.2	...	4.2	...	10.1	...	6.9	...	93.2	....	1.9	9.2	
June 1	3.9	0.4	2.8	0.4	10.1	0.4	7.9	0.4	92.7	80.0	1.9	9.2	

of the proposed method of operation in planning sludge storage. Comparison of the influent and effluent analyses, however, shows that in general less than 10 per cent. of the total daily amount of suspended matter retained is deposited during the night. The

TABLE 47.

EMSCHER TANK (TANK E).

Analyses of Bottom Sludge.

Date	Specific Gravity	Per Cent Moisture	Calculated to Dry Weight, Percentage				Sample taken from Sludge at
			Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble	
1912							
Oct. 25...	1.00	95.5	2.56	73	27	6.5	
Nov. 22...	1.03	93.9	2.40	79	21	7.2	
Dec. 12...	1.02	91.4	2.90	73	27	7.6	
1913							
Feb. 18...	1.02	85.3	2.96	73	27	4.4	
Apr. 23...	1.04	92.0	2.64	67	33	5.3	
June 11...	1.02	92.4	2.64	64	36	7.4	
24...	1.02	92.4	2.72	57	43	5.6	
July 18...	1.03	89.9	2.64	56	44	5.3	
Aug. 19...	1.04	86.8	3.12	..	..	5.0	
Sept. 5...	1.04	93.4	2.88	58	42	...	
Sept. 30...	1.03	84.9	2.17	61	38	6.2	
Oct. 14...	1.02	92.6	2.80	59	41	6.6	Top
14...	1.02	91.0	2.56	56	44	6.0	Bottom
21...	1.01	94.9	3.04	57	43	6.2	Top
21...	1.02	93.7	2.56	56	44	7.2	Bottom
Nov. 6...	1.01	92.8	2.88	61	39	7.3	Top
6...	1.04	92.9	2.80	62	38	6.7	Bottom
20...	1.02	93.0	3.12	67	33	6.2	Top
20...	1.02	93.1	2.96	64	36	6.3	Bottom
26...	1.02	94.5	2.96	61	39	7.6	Top
26...	1.03	92.3	2.96	61	39	6.1	Bottom
Dec. 12...	1.02	95.4	2.96	61	39	9.8	Top
12...	1.02	95.2	2.72	58	42	7.2	Bottom
1914							
Feb. 19...	1.03	88.4	2.88	73	27	9.8	Top
19...	1.06	86.9	2.16	60	40	9.2	Bottom
Mar. 9...	1.04	90.1	2.56	64	36	7.0	
		Tank Remodelled March 9–18.					
27...	1.01	90.0	....	..	..	6.6	Top
27...	1.01	92.9	....	..	..	7.0	Bottom
Apr. 13...	1.02	94.9	2.56	66	34	5.8	Top
13...	1.02	94.6	2.56	68	32	6.3	Bottom
Avg.......	1.02	91.5	2.72	65	35	6.6	
Avg. to Apr. 23, 1913.	1.02	91.5	2.70	75	25	6.4	
Avg. from Apr. 23 1913....	1.03	91.5	2.72	61	39	6.6	

slight scum formation on the surface of the settling chamber was largely grease, with a rate of accumulation, averaging about 0.5 cu. yd. per mil. gal. from the time when first observed.

Samples of sludge were usually taken for analysis when measurements were made. Results obtained on the sludge from the bottom of the tank are shown in table 47, while the composition of the floating scum is indicated in table 48. Analyses of scum from the settling chamber are also given in table 49. The sludge had a specific gravity between 1.01 and 1.04, as removed, with a moisture content averaging 91.5 per cent., a figure higher than is usually noted for sludges from this type of tank. This is practically identical with the results observed on the Dortmund tanks, and may be

TABLE 48.

EMSCHER TANK (TANK E).

Analyses of Top Scum from Gas Vent.

Date	Specific Gravity	Percent Moist.	Calculated to Dry Weight—Percentage			
			Nitrogen	Vol. Matter	Fixed Matter	Ether Soluble
1912						
Oct. 8	1.01	84.9	2.72	75	25	7.0
Nov. 7	0.93	81.9	2.32	71	29	7.2
16	0.97	80.9	2.16	71	29	5.8
Dec. 12	1.01	84.6	2.48	73	27	7.7
1913						
Jan. 11	1.00	84.1	3.28	73	27	10.4
Apr. 4	....	85.0	2.24	71	29	12.5
June 11	0.99	81.9	3.68	83	17	19.4
Oct 14	1.01	84.0	2.64	63	37	14.2
Nov. 6	1.04	83.0	2.32	71	29	14.3
18	1.03	84.2	2.96	69	31	11.0
20	1.02	93.0	3.12	67	33	6.2
26	1.03	86.4	2.88	71	29	15.1
Dec. 10	1.01	85.5	2.96	70	30	13.9
1914						
Feb. 20	1.04	81.9	2.64	77	23	16.4
Mar. 9	1.04	81.0	2.56	73	27	17.6
27*	0.99	86.2	....	..	..	27.8
Average	1.01	84.3	2.72	72	28	12.9

* Tank remodelled March 9 to 18.

due to the comparatively shallow depth of the tank as well as the nature of the settled material. The intense bacterial activity may also be a factor, by reason of the stirring action of the large volumes of gas liberated. Again, the hay, hair and other similar fibrous

TABLE 49.

EMSCHER TANK (TANK E.)

Analyses of Scum from Settling Chamber.

Date	Specific Gravity	Percent Moist.	Calculated to Dry Weight—Percentage				Sample Taken From
			Nitrogen	Vol. Matter	Fixed Matter	Ether Sol.	
1913							
Jan. 4.........	0.89	70.0	....	..	..	40.3	Inside baffle
June 11.........	0.99	84.2	1.84	81	19	21.3	Inside baffle
Nov. 6.........	0.96	85.1	1.84	85	15	34.7	Inside baffle
13.........	1.00	84.0	2.88	86	14	35.4	Inside baffle
13.........	0.98	84.6	2.96	83	17	26.4	Outside baffle
20.........	1.01	83.7	2.96	81	19	27.0	Inside baffle
26.........	1.00	83.0	2.72	85	15	29.7	Inside baffle
26.........	1.02	81.9	3.12	71	29	11.6	Outside baffle
Dec. 2.........	1.01	84.6	3.12	84	16	27.8	Inside baffle
10.........	0.96	80.0	2.64	68	32	14.0	Outside baffle
10.........	0.99	85.3	2.72	82	18	29.7	Inside baffle
17.........	1.01	83.6	....	86	14	....	Inside baffle
17.........	1.00	85.9	....	78	22	....	Outside baffle
1914							
Jan. 3.........	1.02	81.4	....	82	18	....	Inside baffle
3.........	1.03	81.5	....	70	30	....	Outside baffle
Feb. 20.........	1.02	88.5	2.72	83	17	26.8	Inside baffle
Feb. 20.........	1.02	91.7	2.56	72	28	14.8	Outside baffle
Mar. 9.........	1.01	83.9	2.96	81	19	53.4	Inside baffle
Mar. 9.........	1.04	88.0	2.32	71	29	17.3	Outside baffle
Average.........	0.99	83.0	2.64	83	17	32.6	Inside baffle
Average.........	1.01	84.6	2.72	73	27	16.8	Outside baffle

Note: These are all from radial flow tank.

material, occurring in large quantities, may be more retentive of moisture than is the ordinary sludge. The percentage of nitrogen has averaged about 2.72, practically the same as found in the fresh sludge from the Dortmund tank, indicating that the loss of nitrogen in the process of digestion is slight. No decrease in nitrogen content occurred, as the tank ripened. The percentage of volatile matter was high during the first 6 months of operation, when apparently but little digestion of the sludge occurred, the average percentage of volatile matter being 75, or substantially the same as in the sludge from the Dortmund tank, removed at more frequent intervals. The sludge collected on April 23, 1913, showed a distinct decrease in volatile constituents. A still further decrease followed, indicating that ripening was completed about this time and digestion well established. The increase in gas production was practically coincident. The average content of volatile matter, since April 23, 1913, averaged 61 per cent., a considerable reduction.

After October, 1913, sludge was sampled both from the very bottom and top of the layer in the digestion chamber. This differed little in composition. As a rule, the bottom samples contained somewhat less nitrogen and moisture and a slight but not marked decrease in proportion of volatile matter. Probably the contents of the chamber as a whole was thoroughly stirred, with a digestive process more or less uniform throughout the entire sludge mass, rather than progressively increasing in intensity toward the bottom of the sludge chamber.

The scum in the gas vent had a similar composition to the sludge, except for a lower specific gravity, and a moisture content averaging 84.3 per cent. The percentage of volatile and fixed matter is substantially the same, as for the fresh sludge, showing no decrease however with the completion of ripening. There is little difference in the nitrogen content, but the fat content of the scum is somewhat higher.

During the summer a light scum persisted in the inlet compartment of the settling chamber, consisting largely of grease (table 49). Never attaining a depth over a few inches, this did not affect the operation of the tank. It was removed occasionally.

The sludge, when removed from the tank, was very black in color, of a uniform finely granular consistency, flowing readily. Aside from a slight tarry smell, no odor was ordinarily distinguishable, although at times hydrogen sulphide was perceptible. At the first removal, some difficulty was experienced because a plug of the consistency of thick molasses, several feet long, in the outlet pipe had to be removed. Thereafter, little trouble was experienced in drawing off the sludge. Samples of the sludge placed in glass graduates showed the typical Imhoff reaction, the sludge mass rising to the surface in 5 or 6 hr., leaving a layer of clear liquid underneath. With the sludges from other tanks, the reverse was found, the water flushing to the surface.

DIGESTION OF SLUDGE. The deposited sludge was partially digested, not only reducing the volume but also producing a sludge drying more readily than fresh sludge. Once the tank had ripened, digestion proceeded rapidly, with a continuous ebullition of gas, particularly during the warm summer months.

To estimate the actual amount of solid material lost in the process, the total weights of solids applied and removed have been computed, using as a basis the flow records and the analyses of suspended matter. The total amount of solid material accumulated as

sludge and scum has been calculated from the sludge records and analyses. These results are plotted cumulatively in Fig. 13. Although the sludge measurements and analyses are occasionally somewhat erratic, in general a considerable diminution in deposited solids is indicated. The percentage digestion, also plotted cumulatively,

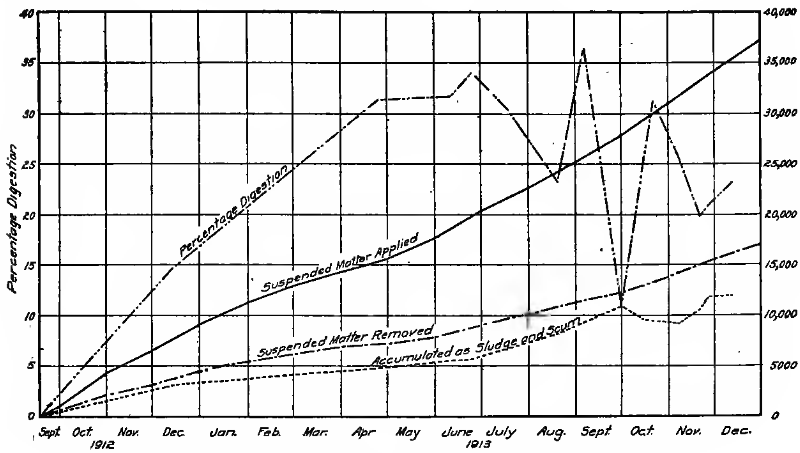


Fig. 13. Digestion of Sludge in Emscher Tank.

shows a range of from about 15 per cent. at the start to slightly over 35 per cent. during the summer of 1913. This substantial reduction of solid material is aided by the high volatile content.

Another criterion is afforded by the change in proportion of volatile constituents in the sludge. The fresh sludge from the Dortmund tanks has contained approximately 75 per cent of volatile matter (cf. tables 35 and 36). The samples from the Emscher tank during the first six months also approached this figure very closely. As the ripening became completed during the spring of 1913, the percentage of volatile matter was markedly diminished, and has remained low ever since (table 47). The loss in volatile matter occurs largely by liquefaction or gassification of portions of the organic products originally present.

Assuming the fixed matter originally present remains unchanged in amount and the fresh sludge to contain 25 per cent. fixed matter, the expression $D = \frac{F-25}{F}$ approximates the percentage of digestion in this case, where F is the percentage of fixed matter in the digested sludge.

This gives a loss varying from 0 at the start to 44 per cent. during the summer of 1913.

The figures obtained by this second method uniformly exceed

those first noted, probably because the latter are cumulative, including the results of the first months of operation when little digestion was going on, whereas the former are based on individual analyses of the sludge. Moreover, the latter results include considerable scum accumulations during the life of the tank, in which apparently no digestion or rotting occurred prior to its removal. Altho the accuracy of this method of comparison may be open to errors, to a considerable degree, it certainly indicates a considerable reduction of organic constituents actually taking place during the storage of the sludge in the digestion chamber.

The ripening period of the tank was apparently about seven months. After several batches of sludge had been removed, however, the rapid accumulation in the chamber necessitated very frequent withdrawals during the fall of 1913. In spite of some withdrawals when the average retention of sludge in the digestion chamber was hardly two months, according to measurements taken, the characteristic appearance and rapid drying qualities were well maintained. The sludge removed on November 6, 1913 dried slower than usual. As several successive removals had been made prior to this date at short intervals, this sludge may have been less completely digested than usual.

CHAPTER IX.

CHEMICAL PRECIPITATION.

GENERAL. The coagulation of sewage by chemicals was one of the earliest forms of sewage treatment, for precipitates are formed by certain reactions, which, in settling drag down the finer particles of suspended matter not ordinarily removed by plain sedimentation. To accomplish a more complete removal of suspended matter than by plain settling, our investigations included lime, iron sulphate, and alumina sulphate. The first experiments were on a laboratory scale in glass graduates, holding 250 or 500 cu. cm., using the effluent from the grit chamber collected during the hours of heavy flow. The results of these preliminary tests (tables 50 and 51) indicate that either sulphate of alumina or copperas and lime remove a comparatively large amount of suspended solids. Sulphate of alumina alone also produced good results. Lime alone produced somewhat inferior results, whereas with copperas alone the removal was no better than by plain sedimentation.

TANK EXPERIMENTS—GENERAL. The preliminary experiments indicated that a substantial improvement might be made by the addition of chemicals, that the trial of the process on a practical scale was justified, and that the efficiency of copperas or sulphate of alumina with lime was but little different. For economical reasons, therefore, the experiments were started with copperas and lime as the precipitants.

METHOD OF INVESTIGATION. The main details of the mixing and controlling apparatus have been described (cf. chap. IV). Lime was added as milk of lime, being mixed with water and agitated continuously by stirring paddles. As first rigged, the stirring apparatus was driven at a speed of about eight r. p. m., but this did not afford perfect mixing. Late in August, 1913, the speed was doubled by suitable pulley reductions, making a more uniform mixing.

At the start both lime and copperas were added as the sewage left the main orifice box, the mixture then flowing directly to the tank with a travel of about 7 ft. Poor results were, however, obtained by this method, a longer mixing period for the lime being apparently required for more complete solution. A baffled trough was accordingly constructed, with a series of narrow channels,

TABLE 50.

INDIVIDUAL LABORATORY EXPERIMENTS.

Reduction in Suspended Matter.

Grains per Gal.		Suspended Matter in Parts Per Million.															
		One Hour Settling Period											Two Hour Settling Period				
Iron or Alum	Lime	Copperas and Lime							Alum and Lime				Copperas and Lime			Alum and Lime	
Original		640	500	700	440	310	670	324	640	500	700	440	500	396	310	700	396
0	0	...	...	...	...	...	...	...	...	...	...	...	...	260	...	...	260
2.5	5	...	...	...	...	...	...	88	...	...	...	...	...	...	...	...	...
3.5	5	...	75	470	...	144	...	...	...	110	370	...	60	132	100	70	104
5	5	152	105	630	...	...	...	...	144	160	340	...	60	168	...	75	156
7.5	5	...	95	620	160	...	...	...	...	140	260	124	65	100	...	35	64
10	5	128	...	...	...	...	...	...	116	...	...	...	...	...	...	...	...
3.5	7.5	...	...	...	123	...	...	...	...	...	...	75	...	...	...	...	...
5	7.5	...	...	...	132	...	148	...	...	...	...	70	...	...	...	...	...
7.5	7.5	...	...	...	149	84	...	...	...	...	...	75	...	...	...	...	...
5	10	140	...	...	...	...	...	...	206	...	...	...	...	...	...	...	...
7.5	10	...	...	...	116	...	...	...	...	...	...	99	...	...	...	...	...
10	10	100	...	...	...	...	...	...	136	...	...	...	...	...	...	...	...
		Per Cent Reduction															
0	0	...	...	...	...	...	...	...	...	...	...	...	...	34	...	...	34
2.5	5	...	...	...	...	...	...	73	...	...	...	...	...	...	...	...	...
3.5	5	...	85	33	...	54	...	...	...	78	47	...	88	67	68	86	74
5	5	76	79	10	...	...	...	...	77	63	51	...	88	58	...	85	61
7.5	5	...	81	11	64	...	...	...	...	62	63	72	87	75	...	93	84
10	5	80	...	...	...	...	...	...	82	...	...	...	...	...	...	...	...
3.5	7.5	...	...	...	72	...	...	...	...	...	...	83	...	...	...	...	...
5	7.5	...	...	...	70	...	78	...	...	...	...	84	...	...	...	...	...
7.5	7.5	...	...	...	66	73	...	...	...	...	...	83	...	...	...	...	...
5	10	78	...	...	...	...	...	...	68	...	...	...	...	...	...	...	...
7.5	10	...	...	...	74	...	...	...	...	...	...	77	...	...	...	...	...
10	10	84	...	...	...	...	...	...	79	...	...	...	...	...	...	...	...

TABLE 51.

LABORATORY EXPERIMENTS.

Reduction in Suspended Matter by Use of Alum, Copperas and Lime Alone.

Grains per Gal.	Suspended Matter in Parts Per Million									
	One Hour Settling Period						Two Hour Settling Period			
	Copperas		Alum		Lime		Copperas	Alum		Lime
Original	1110	1020	1020	810	500	440	1020	830	830	500
0	610	630	630	...	...	...	460	450	450	...
1	...	...	...	...	...	...	...	340	420	...
2	540	...	...	...	...	...	...	420	440	...
3	...	...	...	...	...	...	...	...	420	...
4	460	...	...	...	...	...	...	...	...	...
5	...	...	310	280	125	179	...	...	450	70
7.5	...	...	...	...	...	136	...	...	...	...
10	530	510	220	248	...	...	450	...	...	...
12.5	...	...	...	...	...	108	...	...	...	...
15	...	560	172	...	...	...	440	...	...	...
20	520	510	126	212	...	...	440	...	...	...
	Per Cent Reduction									
0	45	38	...	...	...	...	55	46	46	.....
1	...	...	...	...	...	...	...	59	49	...
2	51	...	...	...	...	...	...	49	47	...
3	...	...	...	...	...	...	...	...	49	...
4	59	...	...	...	...	...	...	...	...	...
5	...	...	70	65	75	59	...	...	46	86
7.5	...	...	...	...	...	69	...	...	...	...
10	52	50	78	69	...	...	56	...	...	...
12.5	...	...	...	...	...	76	...	...	...	...
15	...	45	83	...	...	...	57	...	...	...
20	53	50	88	74	...	...	57	...	...	...

approximately 3½ in. wide, with 180 deg. turns at the ends, making a total distance of travel about 100 ft. The lime solution was added to the sewage at the entrance to the trough, flowing nearly the entire length, before the solution of copperas was added. Owing to the relative elevations of the main orifice box and effluent ring in the tank, it would have been impossible to construct the trough with the proper slope to give a uniform velocity throughout without extensive alterations. The requisite head to overcome friction losses was obtained, however, by backing up the sewage in the orifice box. The velocity in the first half of the mixing box was, consequently, low enough to allow some deposition, but the general results obtained in the tank showed great improvement. In an actual plant with better mechanical appliances, greater efficiency in mixing could be obtained.

CHEMICALS. For convenience in handling, a high grade of hydrated lime packed in 40-lb. bags was used. For a short time, quicklime of good quality was tried, but the labor of slaking, as well as the more rapid deterioration in a damp atmosphere, caused a return to the hydrated lime The lime solution was applied to the sewage at a rate from 20 to 40 gal. per hr. (cf. table 54) regardless of the amount of chemical used, variations in the rate of application being met by changing the strength of the solution. Although the lime used was advertised, as of exceptional quality, considerable impurities were found, as shown in table 52.

TABLE 52.

ANALYSES OF LIME AS DELIVERED.

Date 1913	Percentage of Ca O	Percentage as $Ca(OH)_2$	Remarks
July 17	48.8	64.5	Hydrated lime
21	46.8	61.8	Hydrated lime
23	52.8	69.7	Hydrated lime
Aug. 11	69.4	....	Quick lime
14	80.7	....	Quick lime
18	64.0	84.5	Hydrated lime

As first applied, the lime solution was mixed of the theoretical strength, allowance being made for impurities. As the experiments progressed, it was found, however, that further allowance was necessary on account of unavoidable sedimentation in the mixing trough and orifice box, and after the middle of August, 1913, the rate of application was checked by chemical control, analyses of the solution as discharged from the orifice being made three times daily.

After April, 1914, samples of the lime solution were collected every 2 hr. into a composite for analysis. The actual weight of lime mixed was varied according to the analyses to give a rate as constant as possible.

The copperas was practically a chemically pure product, analyzing on July 17, 1913, 99.3 per cent. of crystalline ferrous sulphate. This was applied in a dilute solution at a rate approximating six gallons per hour variations being made by changing the strength of the solution. During a portion of the time, the rate of application was based on the weight of chemical dissolved. Later, chemical control was established, samples being taken as for the lime solution.

During the summer of 1914, sulphate of alumina was tried, mixed to give the theoretical dose by weight, no analyses being made. The alum, supplied from the filter plant of the Union Stockyards and Transit Co. analyed as follows:

ANALYSIS OF ALUM.

Constituents	Per Cent
$Al_2O_3+Fe_2O_3$	17.80
Fe_2O_3	1.36
Sulphates	48.00
Insoluble	0.57
Water	31.44

OPERATION. Chemical precipitation started on July 15, 1913, with a two-hour period of flow and a theoretical application of 3 gr. of copperas and 5 gr. of lime as CaO per·gal., based on actual weight of chemicals mixed. No better results occurring than those from plain sedimentation, the period of flow was increased to 3 hr. on July 28, 1913. As the results continued to be unsatisfactory, the dose of chemicals was increased to 6 gr. of copperas and 10 gr. of lime per gal. on Aug. 4. On Aug. 12, chemical control of the addition of lime was established. The persistance of inferior results, however, was ended on August 23, by the construction of the lime mixing trough previously referred to. Cleaning was made more frequently thereafter, as unloading due to septic action had been noticed from time to time. With the mixing trough and more careful operation, a decided improvement in the quality of the effluent soon became apparent. Owing to the poor results obtained during the first 1½ months of operation, these experiments are only briefly summarized.

RESULTS OF PRELIMINARY OPERATION. Average results

for the first 1½ months of operation are given in table 53, according to application of chemicals and period of flow.

Table 53 indicates that the removal of suspended matter was somewhat erratic, at the start, and but little better than by plain sedimentation. The removal of organic nitrogen and oxygen consumed was appreciably better, however, than by plain settling.

During the entire period before the installation of the mixing trough, the effluent from the tank was black in color, containing considerable black scaly material in suspension. The sludge as removed from the tank was likewise very black and sticky. Probably this black scale-like substance was ferrous sulphide, resulting from incomplete precipitation of the copperas by the lime and subsequent reduction of the sulphate under the anaerobic conditions developed in the tank Septic action was frequently noted during this period, with consequent unloading of suspended matter. The odor of hydrogen sulphide was distinctly perceptible in the effluent.

TABLE 53.

CHEMICAL PRECIPITATION. REDUCTION OF SUSPENDED MATTER.

Day Samples.

Date 1913	Grains Per Gallon		Period of Flow Hr.	Parts Per Million						Per Cent Reduction		
				Influent			Effluent					
	Copperas	Lime		Org. Nit.	Ox. Con.	Sus. Mat.	Org. Nit.	Ox. Con.	Sus. Mat.	Org. Nit.	Oxy. Con.	Sus. Mat.
July 16 to 25...	3*	5*	2.0	79	232	525	57	128	232	28	45	56
July 25 to Aug.4	3*	5*	3.0	62	219	538	34	125	390	45	43	28
Aug. 4 to 12...	6*	10*	3.0	78	244	570	44	111	288	44	55	49
Aug. 12 to 23...	6*	10†	3.0	67	213	528	36	95	238	46	55	55

* By weight.
† By chemical control.

Experiments made in glass jars required considerably more lime to secure adequate coagulation than that called for by the theoretical reaction taking place between the coagulants. Incomplete mixing and the use of lime for other reactions in the mixture probably accounts for the results noted above, the iron being partially or largely wasted.

TABLE 54.

CHEMICAL PRECIPITATION. OPERATION DATA.

Run No.	Dates (Inclusive) 1913–14 From	To	Total Hrs. Operated	Per Cent of Time Chemicals Applied: Total	Excluding Sundays	Av. Hr. per Day Chem. Appld. Sundays Excl.	Chemicals Applied Grains per Gallon: Lime (CaO) Max.	Min.	Avg.	Copperas Max.	Min.	Avg.	Actual Grains Mixed per Gal.: Lime $Ca(OH)_2$	Copperas	Mixing Water: Gal. per Hour Lime	Iron	Per Ct. Dilution	Period of Flow Hr.
1	Aug. 28	Sept. 23	591.9	48.4	61.0	14.7	12.4	7.6	10.3	6.8	3.1	5.5	16.4	5.5	39.7	5.3	2.2	3.0
2	Oct. 6	Nov. 4	696.3	49.7	57.7	13.9	11.9	6.2	10.2	6.5	2.0	4.5	17.0	4.5	40.0	5.9	2.2	3.0
3	Dec. 15	Jan. 3	450.5	48.4	61.6	14.6	12.2	7.4	9.9	5.8	2.9	3.5	16.4	3.7	38.0	6.4	2.2	3.0
4	Jan. 5	Jan. 17	279.9	55.8	61.0	14.9	10.8	4.8	8.6	4.1	2.6	3.3	15.8	4.2	14.5	7.0	3.0	1.9
5	Jan. 19	Feb. 7	462.1	55.2	61.5	14.7	6.0	3.4	5.1	4.4	2.5	3.5	7.9	3.9	20.0	6.9	3.6	1.9
6	Feb. 16	Mar. 7	451.0	53.6	60.0	14.0*	9.2	3.0	5.1	4.8	2.7	3.5	7.3	3.9	19.2	6.4	1.7	4.0
7	Mar. 18	Apr. 21	815.2	50.2	59.0	14.1	7.0	1.8	5.2	3.6	1.0	2.4	7.5	2.7	20.2	6.5	1.7	4.0
8	Apr. 22	May. 9	417.6	48.0	54.1	13.4	7.0	4.2	5.5	10.3	2.2	5.2	7.5	6.1	18.1	7.6	1.6	4.0
9	May 11	May 31	498.0	48.6	60.3	14.6	7.0	2.1	5.5	6.0	2.5	4.9	8.0	5.1	19.7	6.2	1.0	6.0
10	June 10	June 29	336.0	52.6	61.4	14.8	3.9	1.7	2.8	3.1†	1.2†	2.4†	4.3	2.4†	18.1	5.5†	1.5	4.0
11	July 7	July 28	513.5	52.1	60.7	14.5	....	....	0.0	4.1†	1.0†	3.0†	....	3.0†	....	18.1†	1.2	4.0
12	July 29	Aug. 14	407.0	54.6	61.8	14.8	3.7	1.8	2.7	3.0†	0.0†	1.9†	5.0	1.9†	19.7	4.1†	1.5	4.0
13	Aug. 17	Sept. 9	573.6	51.7	62.0	14.9	...	...	0.0	4.2†	1.8†	3.2†	....	3.2†	....	6.7†	0.4	4.0

* Excluding one day when plant was frozen up.
† Alum.

RESULTS OF INDIVIDUAL RUNS.

OPERATION. The essential data for individual runs after the installation of the lime trough are tabulated in table 54. In general, the chemicals were applied between 8 a. m. and 11 p. m., when the sewage was strong. At night and on Sundays and holidays, no chemicals were used. The average daily number of hours of application was somewhat less than 15, however, owing to occasional unavoidable shut-downs, so that the percentage of total operating time during which the sewage was being precipitated was correspondingly reduced. This was also influenced by the number of Sundays and holidays occurring during a run. The results obtained, therefore, represent a composite of chemical precipitation treatment for a portion of the day, with plain sedimentation for the reminder and on Sundays and holidays.

APPLICATION OF CHEMICALS. Some difficulty was experienced in controlling the application of chemicals with the comparatively crude apparatus at hand, in the small amounts required, hence the dosing and mixing were not as uniform as was to be desired. In an actual plant handling large quantities of chemicals with better mechanical appliances, such difficulties could be largely overcome.

ANALYSES. Analyses of the day samples of effluent for individual runs (tables 55 and 56) are corrected for dilution, due to the water used in applying the chemicals, approximately from 1 to 3 per cent. Sunday results have been omitted.

REDUCTION IN SUSPENDED MATTER. Table 55 shows the average reduction in suspended matter for individual runs, both for the day samples and for the entire 24 hr. The latter represent a composite of chemical precipitation and plain sedimentation. In general, with copperas and lime, approximately 80 per cent. of the suspended matter was removed from the day sewage, with slightly lower results for the entire 24 hr.

The actual efficiency in removing suspended solids initially present in the sewage was probably somewhat greater than appears. With plain sedimentation, this reduction was practically the same for both constituents. With chemical precipitation, the percentage reduction of fixed matter was appreciably less than for volatile matter, probably because of the escape of fine particles of floc. Hence the actual reduction of fixed matter originally present may be the same or perhaps greater than for the volatile constituents. The effluent passing to the outlet nipples frequently showed visually finely divided flocculent matter resembling ferrous hydrate.

TABLE 55.

CHEMICAL PRECIPITATION.

Summary of Removal of Suspended Matter for Individual Runs.

Run No.	Grains Per Gallon		Detention Period Hr.	Mean Upward Velocity Ft. Per Hr.	Suspended Matter in Parts per Million						Per Cent Reduction		
					Influent*			Effluent†					
	Copperas	Lime			Total	Vol.	Fixed	Total	Vol.	Fixed	Total	Vol.	Fixed
					DAY SAMPLES.								
1	5.5	10.3	3.0	3.5	628	478	150	148	93	55	76	81	63
2	4.5	10.2	3.0	3.5	529	413	116	102	57	45	80	86	61
3	3.5	9.9	3.0	3.5	508	387	121	80	45	35	84	88	71
4	3.3	8.6	2.0	2.2	487	397	90	107	75	32	78	81	64
5	3.5	5.1	2.0	2.2	514	419	95	172	129	43	67	69	55
6	3.5	5.1	4.0	2.6	453	372	81	97	71	26	79	81	73
7	2.4	5.2	4.0	2.6	410	345	65	74	56	18	82	84	76
8	5.2	5.5	4.0	2.6	396	309	95	111	62	37	72	80	61
9	4.9	6.0	6.0	1.7	437	353	90	101	62	34	77	83	57
10	2.4‡	2.8	4.0	2.6	378	...	...	138	..	..	64	..	..
11	3.0‡	0.0	4.0	2.6	405	...	...	108	..	..	73	..	..
12	1.9‡	2.7	4.0	2.6	277	...	...	51	..	..	82	..	..
13	3.2‡	0.0	4.0	2.6	388P	...	...	77P	..	..	80P	..	..
					DAY AND NIGHT (24 HOUR) SAMPLES.								
1	5.5	10.3	3.0	3.5	447	345	102	125	83	40	72	76	61
2	4.5	10.2	3.0	3.5	382	292	90	88	54	34	77	82	62
3	3.5	9.9	3.0	3.5	367	266	101	78	45	33	79	83	67
4	3.3	8.6	2.0	2.2	337	271	66	87	61	26	74	78	61
5	3.5	5.1	2.0	2.2	383	298	85	122	88	34	68	71	60
6	3.5	5.1	4.0	2.6	312	253	59	83	63	20	70	75	66
7	2.4	5.2	4.0	2.6	282	236	46	75	55	20	74	77	57
8	5.2	5.5	4.0	2.6	286	216	68	99	62	35	65	71	49
9	4.9	6.0	6.0	1.7	...	...	..	..	..	..	..	..	..
10	2.4‡	2.8	4.0	2.6	261	...	..	125	..	..	52	..	..
11	3.0‡	0.0	4.0	2.6	278	...	..	96	..	..	66	..	..
12	1.9‡	2.7	4.0	2.6	214	...	..	52	..	..	76	..	..
13	3.2‡	0.0	4.0	2.6	279P	...	..	68P	..	..	76P	..	..

* Grit chamber effluent.
† Corrected for dilution.
‡ Alum.
P 14 days only.

REDUCTION OF ORGANIC NITROGEN, FREE AMMONIA, AND OXYGEN CONSUMED. The reduction in organic nitrogen and oxygen consumed for individual runs (table 56) is considerable, though by no means approaching the reduction in suspended matter. A slight increase in free ammonia was uniformly recorded.

REDUCTION IN SOLUBLE CONSTITUENTS. To determine the reduction in soluble matter resulting from chemical precipitation, a few samples of the effluent were analyzed after filtering through absorbent cotton, while the tank was running on a nominal dose of 4½ gr. of copperas and 10 gr. of CaO per gal. Analyses of the corresponding samples of crude sewage were also made after filtration through cotton. The results (table 57) indicate a considerable reduction of soluble organic nitrogen, averaging 15 per cent., and of oxygen consumed, averaging 42 per cent. Once an apparent increase in organic nitrogen was recorded. However, the suspended matter determinations show the removal, on filtering through cotton, in the case of the crude sewage, was not complete, some fine colloidal matter passing through. Undoubtedly the apparent reduction in organic nitrogen and oxygen consumed is affected, as a portion of that recorded as "in solution" may have been in colloidal suspension. The actual reductions, therefore, were probably less than those in table 57.

APPEARANCE OF EFFLUENT. On the whole, the appearance of the chemical precipitation effluent was noticeably better than the turbid effluent of the other tanks, never being as turbid, and at times was very clear, altho, somewhat colored by the soluble iron compounds formed.

SLUDGE ACCUMULATION. The rate of sludge accumulation in general exceeded that for plain sedimentation, partly because more suspended matter was removed and partly because the precipitated coagulants themselves form considerable sludge. Moreover, all the settled material was retained in the bottom of the tank, instead of rising in part to the surface as a comparatively dry scum. Thus the apparent bulk is increased. The rates of accumulation for individual runs (table 58) vary considerably, especially when measured at frequent intervals, due to slight variations in density of the sludge from day to day and the difficulty of accurately measuring small increases in volume The average results over periods between cleanings and for the entire runs are more consistent, however, indicating in general a rate of accumulation frequently 2 to 3 times that by plain sedimentation. With smaller quantities of lime, the sludge accumulation was less voluminous, probably because the iron was not completely precipitated, thus reducing the bulk of floc.

TABLE 56.

CHEMICAL PRECIPITATION.

Reduction in Organic Nitrogen, Free Ammonia and Oxygen Consumed.

DAY SAMPLES.

Run No.	Date 1913–14	Parts Per Million						Per Cent Reduction			Detention Period Hr.	Mean Upward Velocity Ft. per hr.
		Influent			Effluent							
		Organic Nit.	Free Amm.	Oxygen Cons.	Organic Nit.	Free Amm.	Oxygen Cons.	Organic Nit.	Free Amm.	Oxygen Cons.		
1	Aug. 28—Sept. 23	78	22	246	42	24	118	46	9*	52	3.0	3.3
2	Oct. 6—Nov. 4	70	22	256	41	24	134	41	9*	48	3.0	3.3
3	Dec. 15—Jan. 3	87	23	275	62	22	140	29	4	49	3.0	3.3

* Denotes increase.

TABLE 57.

CHEMICAL PRECIPITATION. REDUCTION IN SOLUBLE CONSTITUENTS.

Grains per Gallon:—Copperas, 4.5; Lime, 10.

Determination	Parts per Million				Percentage		
	Crude Sewage	Crude Sewage Filtered	Tank D Effluent	Tank D Effluent Filtered	In Solution	Reduction Total	Reduction in Solution
Organic Nitrogen...	68 65 64	56 45 44	44 39 47	36 39 47	82 69 69	35 40 27	36 13 7*
Average...........	66	48	43	41	73	35	15
Free Ammonia.....	20 19 20	20 19 20	20 21 20	20 21 20	100 100 100	0 10* 10*	0 10* 10*
Average...........	20	20	20	20	100	0	0
Oxygen consumed..	252 237 260	219 197 203	117 135 132	117 127 112	87 83 78	54 43 49	47 36 45
Average...........	250	206	128	119	82	51	42
Suspended Matter..	650 490 460	133 74 120	150 200 70	... ...	20† 14† 26†	77 59 85	.. .. ..
Average...........	533	109	140	...	20†	74	..

* Denotes increase.
† Passing filter.

The results of these experiments are a composite of chemical precipitation for a portion of the day with plain sedimentation for the remainder. By far the greater amount of sludge accumulated during the hours of chemical application, so little deposition apparently taking place from the week night and Sunday sewage, that the use of chemicals at such times appears unnecessary. Hence the results obtained are typical of actual conditions. Occasionally when the tank was cleaned with difficulty, the measurements were discarded. However, the results included are believed to be reasonably accurate.

SCUM FORMATION. With more efficient precipitation, the trouble from scum formation incident to the operation of the plain sedimentation tanks practically disappeared. Scum was entirely absent most of the time, although continually present on the surface of the plain sedimentation tank. Small greenish clots of ferrous

TABLE 58.

CHEMICAL PRECIPITATION.
Removal of Sludge and Scum.

Date	Cu. Yds. of Sludge per Mil. Gal. Since			Remarks
	Last Measurement	Last Cleaning	Start	
1913	Run No. 1, 5.5 gr. Copperas and 10.3 gr. Lime per gal.			
Aug. 28	....	....	....	Started run.
Sept. 4	....	15.0	15.0	1.2 cu. yds. scum removed. Cleaned.
5	14.7	14.7	14.9	
6	0.0	7.1	13.2	Cleaned.
8	6.2	6.6	11.9	
9	4.3	6.2	11.3	
11	36.4	14.8	14.9	Cleaned.
18	19.8	19.8	16.4	Cleaned.
20	32.4	32.4	17.8	
23	20.5	25.0	18.1	End of run. Cleaned.
	Run No. 2, 4.5 gr. Copperas and 10.2 gr. Lime per gal.			
Oct. 6	....	....	....	Started run.
10	20.8	20.8	20.8	Cleaned.
16	....	....	....	0.2 cu. yds. removed.
17	21.8	21.8	21.5	Cleaned.
24	21.4	21.4	21.4	Cleaned.
31	19.7	19.7	20.9	Cleaned.
Nov. 5	31.0	31.0	22.7	End of run.
	Run No. 3, 3.5 gr. Copperas and 9.9 gr. Lime per gal.			
Dec. 15	....	....	....	Started run.
23	13.8	13.8	....	Partially cleaned.
26	31.0	....	....	
1914				
Jan. 3	14.5	17.5	15.8	End of run.
	Run No. 4, 3.3 gr. Copperas and 8.6 gr. Lime per gal.			
Jan. 5	....	....	....	Started run.
8	....	....	....	Removed 3.72 cu. yd.
15	10.2	10.2	....	Removed 1.17 cu. yd.
17	....	....	....	End of run.
	Run No. 5, 3.5 gr. Copperas and 5 gr. Lime per gal.			
Jan. 19	....	....	....	Started run.
26	9.9	9.9	9.9	Removed 0.70 cu. yd.
Feb. 2	13.9	13.9	10.7*	Removed 1.28 cu. yd.
5	11.7	11.7	10.9*	
7	21.4	15.4	12.0*	End of run.
	Run No. 6, 3.5 gr. Copperas and 5.1 gr. Lime per gal.			
Feb. 13	....	....	....	Started run.
19	16.8	16.8	16.8	
28	2.3	8.9	8.9	
Mar. 5	3.1	7.4	7.4	
14	3.5	3.5	6.4*	End of run
	Run No. 7, 2.4 gr. Copperas and 5.2 gr. Lime per gal.			
Mar. 18	....	....	....	Start of run.
20	....	....	....	Tank measured.
27	9.8	9.8	9.8	
Apr. 4	7.9	9.1	9.1	
13	10.5	9.4	9.4	Removed 8.6 cu. yd.
16	12.3	12.3	9.7	
22	7.8	9.3	9.4	End of run.
	Run No. 8, 5.2 gr. Copperas and 5.5 gr. Lime per gal.			
Apr. 22	....	....	....	Start of run.
27	1.6	1.6	1.6	Removed 4 cu. yds.
May 1	8.9	8.9	5.0	
11	9.1	9.0	7.0	Run ended May 9th.
	Run No. 9, 4.9 gr. Copperas and 6.0 gr. Lime per gal.			
May 11	....	....	....	Start of run.
13	6.2	6.2	6.2	Removed 5 cu. yds.
18	15.9	15.9	13.2	
25	8.1	11.3	10.6	Removed 3.8 cu. yds.
June 1	10.0	10.0	10.4	Run ended May 29th.

* Does not include entire run.

hydrate, with suspended matter enmeshed, or a fine black scale-like film, were consistently present on the surface, sometimes in considerable amounts, although never sufficiently to form a continuous mat. The clots probably resulted from the entanglement of the lighter suspended material, such as bits of hay, chaff, etc. When alum was substituted for the copperas, scum formation became pronounced, the alum floc apparently being lighter than the copperas floc, with less weight to hold settled matter down. Similar results were noted in the laboratory experiments.

SLUDGE ANALYSES. Typical analyses (table 59) show a sludge slightly heavier and somewhat lower in moisture than that from the other sedimentation processes. The proportion of volatile matter is distinctly less than in the fresh sludges from plain sedimentation, being about two-thirds as great, doubtless on account of the mineral content added by the chemicals. For the same reason, the nitrogen and fat bear a smaller ratio to the total weight of dry material than in the plain sedimentation sludges.

In general, the sludge run from the tank was of a dirty greenish-gray or black color, with a peculiarly sweet sickish or metallic odor, which was very disagreeable. With the smaller quantities of lime,

TABLE 59.

CHEMICAL PRECIPITATION.

Analyses of Bottom Sludge.

Date	Specific Gravity	Percent Moisture	Calculated to Dry Weight—Percentage			
			Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble
1913						
Aug. 1	1.02	83.3	2.72	69	31	6.1
8	1.01	92.7	2.36	67	33	4.0
15	1.03	89.0	2.08	52	48	4.9
Sept. 4	1.04	88.4	2.56	52	48	4.3
11	1.04	89.8	1.92	46	54	4.0
18	1.04	95.0	1.92	49	51	4.4
25	1.04	89.7	1.92	55	45	5.5
Oct. 10	1.02	92.1	1.76	62	38	5.6
17	1.03	89.6	2.08	54	46	4.8
24	1.04	85.0	2.08	71	29	6.4
Dec. 23	1.03	90.3	2.88	65	35	6.6
1914						
Feb. 9	1.02	91.5	2.24	66	34	9.2
Mar. 27	1.03	91.1	2.16	72	28	9.8
Apr. 27	1.03	89.2	2.16	63	37	9.1
Average	1.03	89.5	2.20	60	40	6.1

the black color became more frequent, due to incomplete precipitation of the iron with consequent reduction to ferrous sulphide, thus giving the sludge its black appearance. The influence of this factor on the volume of sludge deposited has already been noted.

CLEANING. The high rate of sludge accumulation made frequent cleaning imperative, as a tendency to unload was noted when the sludge level was allowed to rise too high in the tank. Septic conditions also developed on too protracted storage, and boiling, accompanied by the rising of sludge from the bottom, was occasionally noted.

In general, cleaning was accomplished with comparativley little difficulty. Occasionally, however, the same trouble developed as noted before, that after a little sludge had been run out, the clear overlying sewage would break through. Septic conditions frequently accompanied these difficult removals.

COST OF CHEMICALS. Lime for all these experiments was obtained from the Marblehead Lime Co. As a basis for estimate, for deliveries in bulk on a large scale, f. o. b. Chicago, a price of \$5.70 was secured per ton with a guarantee of 90 per cent. of CaO and a 1¼ per cent. bonus or penalty for each 1 per cent. variation in either direction, or \$5.40 for an 85 per cent. guarantee with a 1½ per cent. bonus or penalty. This scheme follows the practice at St. Louis, Mo., when obtaining bids on large quantities of lime for water purification. On either basis the theoretical price of pure CaO would be about \$6.35 per ton. The higher grade lime would be preferable, thus costing \$0.455 per million gallons of sewage per grain of CaO per gallon. To cover slight deterioration in storage, imperfect mixing, incomplete solution, etc., this cost may be rounded to \$0.50 per million gallons for 1 grain CaO per gallon.

Although hydrated lime was used for experimental purposes, the use on a large working scale would not be economical, except in a small plant where greater ease of application and lower deterioration during storage would offset the element of lower cost The price quoted per ton was \$7.60, which is equivalent to about \$10.00 per ton of CaO, if 100 per cent. pure.

The copperas, obtained from the American Steel and Wire Co,, is a by-product in the manufacture of steel wire and is sold for water purification purposes under the name of "sugar" sulphate. A price of \$11.00 per ton delivered in barrels or 100-lb. bags, \$10.00 delivered in 200-lb. bags or \$9.00 delivered in bulk was quoted f. o. b. Chicago. 98 per cent. pure $Fe\ SO_4 .7\ H_2O$ is guaranteed, with a claim that 102 or 103 per cent. purity sometimes occurs due to the loss of some

water of crystallization. $9.00 per ton is equivalent to $0.64 per mil. gal. for each gr. per gal. applied. Although this product is of a high degree of purity, deteriorating little on storage, a figure of $0.65 is adopted to cover a slight loss.

Alum in carload lots, at the Union Stockyards, costs about $15.80 per ton, with a content of about 17 per cent. of alumina. This is equivalent to $1.15, in round numbers, per million gallons for each gr. per gal. applied. This is considerably more than the cost of copperas and unless a substantial reduction is possible, either in the amount of lime required or in the amount of coagulant itself, the use of alum would hardly prove economical under these conditions.

THEORETICAL CHEMICAL REQUIREMENTS. The reaction for the combination of copperas and lime may be written

$$CaO+H_2O+Fe\ SO_4\ .7\ H_2O=Ca\ SO_4+Fe\ (OH)_2+7H_2O,$$

The theoretical combining weights of the iron and lime are in the proportion of 56 to 278. Hence 1 gr. of copperas should require approximately 0. 19 gr. of lime for complete precipitation. This would indicate that only a small portion of the lime added is required by the iron.

Ordinarily sewage is alkaline, but the alkalinity is usually bicarbonate alkalinity. Observations at the Lawrence testing station years ago indicated that the precipitation of the iron did not occur in the presence of bicarbonate alkalinity, but only when lime was present as hydrate or normal carbonate. Hence an excess of lime is required to combine with the iron, and excess of CO_2 over that required to form bicarbonate. Possibly an excess combines directly with the organic matter present. Experiments made in glass jars, adding copperas at the rate of 3½ gr. per gal. showed an acid reaction to phenolphthalein with approximately 3 gr. of lime per gal., whereas 4 gr. produced an alkaline reaction. In both cases, the precipitation of ferrous hydrate was very slight The use of 5.5 gr. of lime produced a fair precipitate, while with greater amounts the coagulation was correspondingly more rapid. However, after a considerable period of settling the results obtained with the lower amounts of lime appeared visually substantially as good as those with the higher amounts. With lime alone, about 1½ gr. per gal. was necessary to make alkaline to phenolphthalein.

To confirm the small scale tests, further experiments were made in barrels, holding about 40 gal., by adding 3½ gr. of copperas per gal. and lime at the rate of 4 and 5 gr. per gal. Both barrels were thoroughly stirred after adding the lime. With the greater amount

of lime, a heavy floc quickly formed while with the smaller amount, the precipitate was somewhat slower in forming and was more finely divided. However, at the end of 2 hr., a very clear supernatent liquor was obtained from both barrels, samples taken about 6 in. below the surface containing only 76 and 40 p. p. m. of suspended matter, respectively. With the lower amount of lime, a very slight turbidity was noted at the end of 2 hr., but with the higher dose none was observable. A third barrel of sewage settled without the addition of chemicals contained 272 p. p. m. of suspended matter at the end of 2 hours.

These experiments indicate that, with very thorough mixing, from 4 to 5 gr. of lime per gal. are required for the precipitation of this sewage, using 3½ gr. of copperas per gal. As the utilization of the lime may not be complete, somewhat more or at least 5 gr. per gal., would be required in actual practice. These experiments were all made during the winter months. Seasonal variations in the character of the sewage may extend these limits. Barrel experiments showed that a good floc occurred with alum alone in amounts varying between 2.5 and 5 gr. per gal. If the use of lime can thus be dispensed with, it is possible that alum may prove slightly more economical than copperas.

CHAPTER X.

SLUDGE TREATMENT.

GENERAL. In any tank treatment of sewage, the disposal of the sludge needs careful consideration. With the Center Ave. sewage, the exceptionally large volume of sludge per million gallons renders this phase of the situation of particular importance. Sludge, removed from the settling tanks, is a viscous semi-liquid mass, high in moisture. The first step in its disposal ordinarily involves the reduction of the contained moisture to a sufficient degree to allow the sludge to be readily handled. In the past this has generally been accomplished by land drying, under suitable conditions, either natural or artificially created, or by some mechanical means such as pressing, centrifuging, or the like.

In these investigations drying on underdrained beds of sand has been tried, and the feasibility of drying sludge by filter-pressing has been tested. A number of samples were analyzed for calorific values. Other samples were analyzed to determine the value as a fertilizer.

BEDS. Of the sludge beds already described (cf. chap. IV), the underdrained beds were built up of the following material, the sand forming the top layer, and the depths being measured at the center of the filter:

Position	Material	Depth in Inches
Bottom	$1\frac{1}{4}$ to 2 inch stone	2
	Concrete stone	$1\frac{1}{2}$
	Roofing gravel	$1\frac{1}{2}$
Surface	Torpedo sand	1

During the summer and fall of 1913, most of the beds were re-sanded to a depth of about 2 inches.

CHARACTER AND AMOUNT OF SLUDGE. Sludge and scum accumulated in varying amounts in the various tanks. In general a rate of from about 1 to 14 cu. yd. of sludge and from 1 to 13 cu. yd. of scum per mil. gal. were accumulated in the Dortmund tanks with plain sedimentation, based on the results of individual measurements. Long term averages gave a rate of about 3 cu. yd. of sludge and 3 cu. yd. of scum per mil. gal. for Tank C, while the corresponding figures for Tank D were approximately 6 and 3.5 cu. yd. for sludge and scum respectively. The Emscher tank averaged about 7

cu. yd. of sludge and 1.3 cu. yd. of scum per mil. gal. for its entire period of operation. Individual measurements during early operations sometimes showed a negative increase. During the summer of 1913, no scum was removed. In chemical precipitation, the volume of sludge fluctuated greatly, exceeding 30 cu. yd. per mil. gal. at times. These figures for sludge are all based on the volumes measured in situ in the tanks. As treated on sludge beds these volumes would necessarily be somewhat greater, since the removal of a certain amount of the overlying sewage seems to be unavoidable, when complete sludge removal is attempted.

TABLE 60.

VARIATION IN MOISTURE CONTENT OF SLUDGE.

Source	Per Cent Moisture								
	Sludge						Scum		
	In Tank			On Bed			On Bed		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
Tank C........	89.5	92.7	90.9	91.7	98.1	94.9	79.8	84.4	83.4
Tank D........	....	....	....	91.8	98.9	94.5	79.0	86.7	82.3
Tank E........	84.3	94.7	91.4	92.1	95.1	93.2	....	....	80.9
Chem. Pre......	83.3	92.1	89.5	88.5	96.2	92.5	81.3	93.2	86.3

Table 60 shows that the sludge as applied to the beds averaged about 94 per cent. moisture, with maximum variations in either direction of about 4 per cent. The scums averaged about 13 per cent. less in their moisture content. For the sludges, there is some increase in moisture on withdrawal, the resulting increase in volume of sludge being considerable.

The sludge from the Emscher tank was uniformly black, with a fine-grained even texture, whereas the sludges from the other sedimentation processes, including chemical precipitation, were smoother in texture as a rule and more sticky. The scums were sticky, containing much fibrous material.

DRYING BEDS, GENERAL. Tables 61, 62, 63 and 64 record the depths of sludge applied to the beds, the original moisture content, the time required to bring the sludge to a proper condition for handling, with percentage reduction in volume and moisture content at that time. The final moisture content after varying periods of drying on the ground, following removal from the beds, is also shown together with pertinent meteorological data.

TABLE 61.

SLUDGE DRYING EXPERIMENTS.

Record of Sludge and Scum Drying for Dortmund Tank (Tank C).

Removed from Tank			Removable from Bed						Dried on Ground		Remarks.
Date	Depth on Bed Feet	Percent Moist.	Days Elapsed	Depth on Bed Feet	Percent Moist.	Percent Reduc. Volume	Precip. Inches	Avg. Temp. Deg. Fahr.	Days Elapsed	Percent Moist.	
SLUDGE											
1913											
July 18	1.17	91.7	12	0.50	74.4*	57	0.15	74	88	35.6	* After 6 days
Aug. 2	0.60	92.7	7	0.15	....	75	0.85	78	73	51.4	
29	1.00	96.9	12	0.23	67.2	77	0.06	75	105	64.6	
Sept. 22	1.80	97.6	22	0.56	76.2	69	1.09	60	83	69.2	
Oct. 3	1.31	93.8	11	0.52	76.1	60	0.05	64	...	....	
17	1.00	97.0	..	0.26*	76.7*	74*	....	..	60	72.2	* After 19 days
Nov. 7	1.88	98.1	13	0.55	79.4	71	0.13	46	...	....	
1914											
Apr. 9	1.11	96.4	9	0.30	76.0	73	0.02	48	...	....	
9	1.73	91.8	9	0.40	78.5	77	0.02	48	...	....	
May 1	0.92	92.9	17	0.42	72.6	46	2.88	54	...	....	
SCUM											
1913											
July 9	0.21	81.2	9	....	62.6	..	2.39	73	97	50.9	
18	0.49	79.8	23	0.29*	....	42	1.09	75	88	45.9	* After 26 days
Aug. 2	0.33	84.4	10	0.19	....	42	1.35	75	73	50.2	
15	0.82	84.4	12	0.53	76.5*	35	0.63	75	119	57.6	* After 7 days
29	0.74	83.6	12	0.29	70.8	61	0.06	75	105	62.4	
Sept. 22	0.80	83.6	10	0.48	76.5	40	0.30	60	85	67.5	
Oct. 3	0.38	83.5	11	0.28	73.5	26	0.05	64	74	66.3	
17	0.41	83.7	11	0.29*	74.5*	29*	0.63	44	..	....	* After 18 days
Nov. 7	0.29	86.3	13	0.20	77.1	31	0.13	46	..	....	

TABLE 62.

SLUDGE DRYING EXPERIMENTS.

Record of Sludge and Scum Drying for Old Dortmund Tank (Tank D) for Plain Sedimentation.

Removed from Tank			Removable from Bed						Dried on Ground		Remarks
Date	Depth on Bed Feet	Per Cent Moisture	Days Elapsed	Depth on Bed Feet	Per Cent Moisture	Per Cent Reduction Volume	Precipitation Inches	Average Temp. Deg. Fahr	Elapsed Time Days	Per Cent Moisture	
					SLUDGE						
1912											
Oct. 7	1.39	98.9	16	0.46*	75.5	67*	2.40	55	112	63.2	*After 13 days.
25	1.01	91.8	17	0.73*	....	28*	1.63	48	94	64.0	*After 14 days.
Nov. 9	1.88	95.8	13	0.83	74.6	56	0.47	47	79	38.5	
22	1.92	92.1	14	1.22	....	36	0.63	39	...	....	
1913											
Mar. 27	2.08	96.0	6	0.85*	74.0*	59*	0.00	63	...	....	*After 10 days.
July 7	0.86	92.6	11	0.23	....	73	3.13	73	...		
					SCUM						
1912											
Nov. 18 to 22	0.82	81.3	9*	0.74*	76.7*	10*	0.10	38	70	71.9	*Barely removable
Dec. 3 to 12	1.65	85.0	14	1.58	81.2	4	....	..	...	....	
1913											
May 22	0.39	80.6	7	0.33	....	8	1.98	78	140	47.7	
June 19	0.58	81.0	29	0.39	71.5	33	4.02	76	117	60.7	
July 1	0.58	79.0	23	0.38	69.0	34	3.35	74	143	53.5	
7	0.57	86.7	17	0.39	80.8	32	3.26	72	99	53.8	

TABLE 63.

SLUDGE DRYING EXPERIMENTS.

Record of Sludge and Scum Drying for Emscher Tank (Tank E).

Date	Removed from Tank			Removable from Bed					Dried on Ground		Remarks
	Depth on Bed Feet	Per Cent Moisture	Days Elapsed	Depth on Bed Feet	Per Cent Moisture	Per Cent Reduction Volume	Precipitation Inches	Average Temp. Deg. Fahr	Elapsed Time Days	Per Cent Moisture	
1913						SLUDGE					
June 24	0.72	93.8	7	0.32	64.1	56	0.15	82	..	....	
July 18	1.52	92.1	8	0.72	....	53	0.15	70	88	59.1	
Sept. 5	1.09	92.1	6	0.55	75.4	50	0.05	72	98	60.0	
30	2.03	93.0	6	0.84*	76.4*	59*	0.34	64	78	73.5	*After 14 days.
Oct. 14	2.01	93.6	6	0.88*	78.8*	56*	0.51	52	..	....	*After 22 days.
Nov. 6	1.90	95.1	14	0.65	78.0	66	0.13	46	..	....	
1914											
Apr. 13	0.54	92.4	4	0.30	78.5	45	0.00	52	..	....	
1912						SCUM					
Nov. 7	1.47	80.9	18	1.47	78.9	0	0.57	45	81	52.8	
Nov. 16 to 19	1.06	....	13	....	79.4*	..	0.26	40	67	59.1	*After 22 days.

TABLE 64.

SLUDGE DRYING EXPERIMENTS.

Record of Sludge and Scum Drying for Chemical Precipitation Tank (Tank D).

Removed from Tank			Removable from Bed						Dried on Ground		Remarks
Date	Depth on Bed Feet	Per Cent Moisture	Days Elapsed	Depth on Bed Feet	Per Cent Moisture	Per Cent Reduction Volume	Precipitation Inches	Av. Temp. Deg. Fahr.	Elapsed Time Days	Per Cent Moisture	
					SLUDGE						
1913											
Aug. 1	1.98	95.1	24	0.51*	74.8*	74*	2.49	75	134	63.5	*After 27 days.
8	1.89	93.1	19	0.57	74.9	70	1.69	75	...	....	
15	2.03	91.5	22	0.64	83.4	69	0.64	75	...	....	*After 7 days.
Sept. 4	1.95	90.7	28	0.73	74.5	63	1.55	63	99	63.0	
4	0.98	99.1	6	0.15	60.0	85	0.05	72	99	48.8	
11	0.95	97.7	19	0.22	70.0	77	1.50	60	96	60.7	
Oct. 10	0.84	96.7	16	0.24*	71.0*	71*	1.62	50	67	67.0	*After 26 days.
1914											
Apr. 13	0.87	88.8	11	0.56	73.1	36	0.02	52	...	....	
27	0.88	89.1	18	0.47	66.6	47	3.03	57	...	....	
27	1.53	88.5	25	0.82	69.5	46	3.03	59	...	....	
May 13	1.13	89.7	12	0.62	68.9	45	0.00	57	...	....	Bed uncovered.
13	1.26	89.5	28	1.12	70.0	11	2.92	58	...	....	" covered.
					SCUM						
1913											
Aug. 1	0.84	81.3	24	0.61*	....	27*	2.49	75	134	58.3	*After 20 days.
8	1.21	93.2	14	....	77.6	...	1.69	75	126	70.9	
15	0.53	84.4	12	0.33*	71.1	38*	0.64	75	119	56.1	*After 6 days.

DEPTH. Sludge was run onto the beds in depths, up to 2 ft., that being the maximum capacity of the bed. The depth of application of scum was usually less than 1 ft., owing to the small quantities ordinarily removed.

At the time of removal from the bed, the diminution in volume of the sludges ranged from 28 to 85 per cent. Ordinarily, however, a reduction of between about 60 and 75 per cent. occurred, the variations of course depending largely on the original moisture content of the sludge and the content at time of removal. The sludge from the Emscher tank appeared to diminish slightly less in volume than that derived from other sources, possibly on account of the porous character, by which the contained water drained away with less disturbance to structure than was the case in other sludges. The initial depth on the bed did not always control the final volume, for, as the decrease is primarily a function of reduction in moisture, the original depth of application would have little effect in this particular.

The scums consistently showed a considerably smaller decrease in volume because of the lower initial moisture content and smaller total loss of moisture. The reductions ranged from 0 to 61 per cent., being ordinarily from 30 to 40 per cent.

TIME OF DRYING. Considerable difference was noted in the time of drying of sludges from the different tanks. The Emscher tank sludge showed a marked superiority, in warm dry weather the surface being usually dry within 24 hours after removal from the tank, with surface cracks beginning to appear and the sludge drawing away from the sides of the bed. Within six or seven days, the sludge was consistently spadeable and removable even though applied in depths as great as 2 ft. In case of necessity, this time could probably be reduced somewhat. No water ever appeared on the surface of the sludge, the porous character of the mass apparently allowing rapid drainage. Samples placed in a glass graduate showed the characteristic behavior of Emscher sludge, the sludge mass rising to the surface in 5 or 6 hr., leaving a layer of clear liquid underneath. This process was reversed for the Dortmund and chemical precipitation sludges, the liquid rising to the top.

With sludge from plain sedimentation tanks of the Dortmund type, the time required for drying varied from 6 to 22 days, the minimum time of 6 days occurring but once, few sludges of this sort being removable in less than 12 days. Several factors influence the variations noted, such as the meteorological conditions prevailing during the drying interval, original depth on bed, moisture content and variations in consistency. The sludges from the Dortmund

tanks were much more sticky than the Emscher sludge and parted with their moisture much less readily. Surface evaporation undoubtedly played a more important part in their drying, as water frequently rose above the surface to a depth of several inches.

The scums, in spite of their initially lower moisture content and uniformly thinner depth of application, frequently required a longer interval for drying. The fibrous material, prominent in their composition, was very retentive of moisture. Even where very thin layers were applied, the scum remained sticky for long intervals. In depths from 0.21 to 1.65 ft., the required drying period ranged from 7 to 29 days, 10 or 11 days being ordinarily a minimum.

For chemical precipitation sludge, the drying period was usually more prolonged than for the plain Dortmund sludge. The gelatinous iron hydrate present in the sludge apparently interfered with the removal of moisture. At certain times the solid matter settled to the bottom of the bed, the water rising to the top. Then surface evaporation was probably primarily responsible for drying, whereas at other times the sludge remained in one sticky mass for days at a time. Septic conditions sometimes developed after application to the beds, large quantities of gas being liberated. The difference in drainability of the various sludges was brought out by the behavior of the underdrains. When Emscher sludge was applied to the beds, the drains begin flowing freely almost immediately, showing the drying to be largely due to the escape of water from below. With the chemical precipitation sludge on the other hand, the underdrains were frequently very slow to begin discharging and the amount of water removed in this manner was much less. With applicatons from 0.84 to 2.03 ft. deep, the period of drying varied from 6 to 28 days. The sludge requiring 6 days was an exceptionally thin sludge applied to a depth of about 1.0 ft. Ordinarily 18 to 20 days were required during hot summer weather.

REDUCTION OF MOISTURE. When removed from the sludge beds, the contained moisture ordinarily averaged from 70 to 77 per cent. In this condition the sludges were somewhat moist, especially in the interor of the mass, but could be readily spaded.

After removal from the beds, they were placed in small piles on the ground in the vicinity of the plant. On some occasions, however, the sludge was not removed immediately on reaching a spadeable condition. Protracted periods of drying, from 67 to 112 days (including time on beds), showed final moisture contents varying between about 35 and 70 per cent. Climatic conditions largely affected these results, but during the summer and fall, a reduction to

50 or 60 per cent. moisture ordinarily obtained, the sludges then appearing comparatively dry and earthy.

CLIMATIC CONDITIONS. The sludge beds were constructed in the open, sheltered on the south and west by the tanks, but otherwise exposed freely to the sun, air and weather. The figures for precipitation in the tables are taken from the daily records at the testing station rain gauge, while the air temperatures are taken from the monthly summaries of the U. S. Weather Bureau.

Weather conditions undoubtedly affected the drying of sludge to a considerable extent. The sludge from the Emscher tank probably suffered less from low temperatures and heavy precipitation than did the other sludges, since the withdrawal of water was apparently largely from below and the sludge was more porous and easily drained. In the other sludges, surface evaporation appeared of greater importance as the water frequently flushed to the surface, remaining until evaporated. Consequently warm dry weather would aid quicker drying. The non-porous character of the sludge also retained moisture falling on its surface, thus delaying the drying. The effect of covering the beds was studied during the spring of 1914 (table 64), when one sludge was run out to equal depths on two beds, one having an opaque cover. The covered bed required a considerably longer interval for drying, and on removal the residual moisture content was somewhat higher than for the uncovered sludge.

During the winter of 1912, the sludge on the beds froze during December, remaining frozen until spring. Further reduction of moisture was largely prevented. With tank treatment requiring the discharge of fresh sludge at frequent intervals, considerable reserve sludge area would be required, as the freezing of the sludge on the beds interferes with removal as well as drying. The freezing and consequent expansion of the sludge mass may, however, have a helpful effect in rendering it more porous, thus facilitating drying with the return of warm weather.

ODOR. The sludge removed from the Emscher tank was inoffensive, although traces of hydrogen sulphide occasionally were found. On the beds and dried, this sludge was entirely inoffensive, having only a slight tarry odor, noticeable only close to. The sludges from other sources were frequently offensive on removal, and, while drying, odors were noticeable in the immediate vicinity of the beds. The scum from the gas vent of the Emscher tank was, however, offensive in odor, though not as markedly as the sludge from other tanks.

FILTERING MATERIAL. No filtering material was renewed

until the fall of 1913, when all of the sludge beds, except No. 2, were resanded to a depth of about two inches. The entire sand layer had then been removed, the sludge being discharged directly upon the underlying gravel. The remaining material was thoroughly washed to remove sludge which had penetrated into the deeper layers, and was graded in size in replacing. The dates of renewal, the approximate amounts of sludge previously treated per square foot of area, and the number of applications of fresh sludge are given in table 65.

TABLE 65.

HISTORY OF SLUDGE BEDS.

Bed No.	Date Resanded 1913	Cu. Yd. Sludge Treated per Sq. Ft.	No. Applications of Sludge (Bed cleaned)
1	Sept. 20	0.21	7
2	Not resanded		
3	Oct. 4	0.34	7
4E	Sept. 20	0.30	9
4W	Sept. 20	0.26	8
5E	Oct. 14	0.39	7
5W	Oct. 3	0.39	6
6	Oct. 14	0.32	7

The original depth of sand on all beds was one inch. If entirely removed when the beds were resanded, an average of one-eighth of an inch might be charged against each cleaning. Cleaning during the winter, when the beds were frozen, probably removed more as frozen sand, adhering to the overlying sludge, came away in large quantities. Ordinarily the adhesion between the sand and sludge was very slight, only a very thin surface coating appearing on the bottom of the sludge. When discharged directly on the gravel, the adhesion was greater, the liquid sludge apparently flowing into voids of the gravel, keeping the stones embedded when dry. With careful operation, it seems as though 12 to 15 cleanings would be the maximum per inch of sand.

UNDERDRAINAGE. With the Emscher tank sludge, the underdrains began flowing freely almost as soon as the sludge was run on, showing the ready drainability of this sludge. With the other sludges the discharge was less rapid as a rule and smaller in amount. In the analyses made of the effluent from the underdrains (table 66), occasional high results for organic nitrogen and oxygen consumed occurred, but as a rule the former constituent was low in amount. The free ammonia was universally high, indicating apparently that some oxidization of the organic nitrogenous matter had taken place. There was little nitrification, however. The liquid was normally

yellowish in color and clear, and being small in amount could probably be discharged with the tank effluent, or passed to sprinkling filters.

TABLE 66.

SLUDGE DRYING EXPERIMENTS.

Analyses of Effluent from Sludge Bed Underdrains. Plain Sedimentation Sludge from Dortmund Tank (Tank D).

Date 1912	Parts per Million					Remarks
	Nitrogen as				Oxygen Cons.	
	Organic Nitrogen	Free Ammonia	Nitrites	Nitrates		
Oct. 7	....	....	0.064	0.94	76	First flow
8	....	....	0.000	0.23	67	Second day
9	....	....	0.000	0.28	61	Third day
25	157	14.4	0.002	0.29	82	First flow
26	53	135	.....	....	107	Composite
Nov. 9	9	79	0.150	0.00	47	First flow
9	12	88	0.000	0.00	50	Composite
22	15	125	0.440	1.00	63	First flow
22	12	148	0.110	0.31	63	Composite
Dec. 4	58	110	0.004	0.72	101	First flow
4	33	119	0.004	0.60	80	Composite

FLIES. During the summer, the surface of slow drying sludge on the beds became baked to a thin hard crust, under which prolific growths of maggots were frequently uncovered. The same phenomenon occurred on the surface scum on the tanks. The drying sludge apparently affords a very favorable breeding place for flies. With quick drying sludge this condition does not prevail.

MINERALIZATION OF SLUDGE. Typical analyses of the changes in nitrogen, fat and volatile content of air-drying sludges (tables 67 and 68) show that after 2 to 4½ months of drying on the sludge beds and on the ground, the sludges and scums from all sources consistently decrease in percentage of volatile constituents. This may be due in part to leeching out of the volatile matter by the rains, but in the main it represents true mineralization or volatilization of the organic contents of the sludge. The reduction in percentage of volatile matter varied from 4 to 34 per cent., the well-digested Emscher sludge and the sludge from chemical precipitation showing in general the smallest loss of volatile matter. The latter sludge, containing a large volume of iron hydrate, is initially lower in volatile matter than the other fresh sludges. In some cases a perceptible decrease in volatile content was noted after but a brief period of drying.

TABLE 67.

SLUDGE DISPOSAL.

Reduction in Nitrogen, Fat and Volatile Matter in Sludge on Protracted Drying.

Date	Original Sludge				On Bed					Final—On Ground				
	Dry Weight, Percentage				Elapsed Days	Dry Weight, Percentage				Elapsed Days	Dry Weight, Percentage			
	Nit.	Vol. Matter	Fixed Matter	Ether Soluble		Nit.	Vol. Matter	Fixed Matter	Ether Soluble		Nit.	Vol. Matter	Fixed Matter	Ether Soluble
					DORTMUND (Tank D) SLUDGE									
1912														
Oct. 7...	2.24	69	31	9.7	32	....	69	31	....	112	2.64	61	39	6.5
25...	2.64	80	20	7.8	..	....	..	..	....	94	2.96	46	54	4.6
Nov. 9...	2.32	70	30	8.6	14	2.56	63	37	....	79	2.56	41	59	4.8
Dec. 4...	3.44	78	22	10.0	..	....	..	..	....	128	2.48	67	33	...
1913														
Jan. 17...	3.36	76	24	8.0	..	....	..	..	....	116	2.80	59	41	...
Apr. 4...	2.56	74	26	7.7	..	....	..	..	....	76	2.48	71	29	...
July 7...	3.04	70	30	8.6	17	2.56	65	35	....	137	2.72	51	49	5.6
					DORTMUND (Tank C) SLUDGE									
1913														
July 18...	2.56	69	31	7.1	13	2.24	60	40	....	88	2.08	51	49	...
Aug. 2...	2.80	74	26	6.2	11	2.80	66	34	....	73	2.56	53	47	...
					EMSCHER SLUDGE									
1913														
July 18...	2.64	57	44	5.3	..	....	..	..	....	88	2.32	50	50	...
Sept. 5...	2.88	58	42	...	..	....	..	..	....	98	2.64	48	52	3.1
30...	2.72	61	39	6.2	..	....	..	..	....	77	2.56	46	54	4.4
					CHEMICAL PRECIPITATION SLUDGE									
Aug. 15...	2.08	52	48	4.9	..	....	..	..	....	60	2.00	48	52	...
Sept. 4...	2.56	52	48	4.3	..	....	..	..	....	98	1.76	37	63	3.4
11...	1.92	46	54	4.0	..	....	..	..	....	96	1.84	39	61	3.2
Oct. 10...	1.76	62	38	5.6	..	....	..	..	....	66	1.68	42	58	4.5

TABLE 68.

SLUDGE DISPOSAL.

Showing Reduction in Nitrogen, Fat and Volatile Matter in Scums on Protracted Drying.

Date	Original Scum				On Bed					Final—On Ground				
	Dry Weight, Percentage				Elapsed Days	Dry Weight, Percentage				Elapsed Days	Dry Weight, Percentage			
	Nit.	Vol. Matter	Fixed Matter	Ether Soluble		Nit.	Vol. Matter	Fixed Matter	Ether Soluble		Nit.	Vol. Matter	Fixed Matter	Ether Soluble
					DORTMUND (Tank D) SCUM									
1912														
Nov. 22...	3.36	74	26	10.4	7	3.04	72	28	...	70	2.96	70	30	8.5
Dec. 24...	3.52	72	28	9.7	..	....	..	..	...	118	2.80	75	25	...
1913														
May 22...	2.96	75	25	7.8	..	....	..	..	...	145	2.48	57	43	...
June 10...	2.16	73	27	7.2	..	....	..	..	...	126	2.16	53	47	...
19...	2.16	73	27	9.2	29	2.56	61	39	7.1	117	2.48	56	44	...
July 1...	2.16	70	30	8.7	23	2.52	66	34	...	144	2.48	56	44	...
7...	2.48	70	30	9.1	17	2.64	66	34	...	99	2.24	56	44	...
					DORTMUND (Tank C) SCUM									
1913.														
July 9...	2.56	72	28	7.4	9	2.48	52	48	6.2	97	2.48	58	42	...
18...	2.64	70	30	7.7	26	2.52	63	37	...	88	2.48	56	44	...
Aug. 2...	2.88	62	38	7.2	11	3.12	65	35	...	73	2.24	76	24	...
15...	2.40	69	31	6.9	14	2.96	57	43	6.6	...	....	..	..	...
					EMSCHER (Tank E) SCUM									
1912														
Nov. 7...	2.16	71	29	5.8	18	2.72	72	28	...	82	2.96	60	40	6.4
29...	2.56	73	27	...	..	....	..	..	...	60	2.16	61	39	...
Dec. 12...	2.48	73	27	7.7	..	....	..	..	...	130	2.32	69	31	...
					CHEMICAL PRECIPITATION SCUM									
1913														
Aug. 1...	2.64	62	38	8.7	..	....	..	..	...	134	2.32	50	50	3.2
8...	2.56	67	33	4.5	..	....	..	..	...	126	2.32	42	58	4.7
15...	2.32	61	39	7.3	14	3.04	68	32	4.4	119	2.16	43	57	5.2

In general, the nitrogen content showed a decrease after protracted drying, though not universally. The occasional increase found may be due to lack of representative sampling as an actual increase would hardly be expected. A loss in fat was noted consistently when this determination was made on the dried sludge.

GRIT CHAMBER SLUDGE. When the grit chamber was cleaned, the sludge was flushed into the waste drain. No drying experiments were made. However, this sludge was low in moisture and organic matter and being small in amount, should offer no difficulty in handling.

SECONDARY SETTLING BASIN SLUDGE. Very little has been done with this sludge, but the indications are that in thin layers it will dry very readily, largely from below, in this respect resembling the Emscher tank sludge.

SLUDGE PRESSING.

APPARATUS. During the fall of 1913, experiments were made on pressing sludge to reduce the moisture content, with an apparatus consisting of a filter press, a pump for forcing the sludge into the press under pressure, a storage reservoir for the sludge, with the necessary piping and valves, all located just south of the screen-house.

The filter press, of the Kelly type, loaned by Mr. Emil E. Lungwitz of New York City, consisted of a riveted steel cylinder 18 in. long and 9½ in. in diameter inside, mounted horizontally. The end opening was surrounded by a steel bearing collar and was closed, when in operation, by a cast steel door sliding on horizontal guides attached to the frame. A tight joint was secured by means of a circular rubber gasket inserted in the bearing collar against which the door was forced tightly by 4 wedges engaging in U bolts and tightened by a hand screw arrangement. The filter leaves, mounted on the door frame, consisted of two parallel flat bags of heavy woven fabric 12 in. long, 6 in. wide and 2 in. apart stretched over rectangular perforated pipe frames forming the outlets for the liquid removed in pressing. For further stiffening, pieces of heavy mesh screen were inserted inside each leaf. The total effective filtering area was 2.0 sq. ft. The filtrate passed through ¼ in. pipes leading from the filter leaves through the steel door. The material to be filtered entered at the bottom of the press through a one-inch pipe. A pressure gage was attached.

For forcing the sludge into the press, a Kinney Rotating Plunger pump, loaned through the courtesy of the local agent, Mr. Carl Heim, was employed, consisting essentially of a cylindrical plunger

rotating inside the pump casing on an eccentric shaft. The liquid is drawn in through the pump suction till the capacity for a single stroke is reached, when the supply is automatically cut off by the bearing of the plunger against the pump casing, and at the same time the discharge is opened. All these operations are effected by the eccentricity of the shaft and the design of the suction and discharge ports and pump casing. The construction is simple, free from valves, seemingly well adapted for handling sludge. The pump supplied had ¾ in. suction and discharge openings, and, at a speed of 600 r. p. m., was rated at a capacity of 6 gallons a minute. It was driven by a 1 h. p. induction motor, 1800 r. p. m., belted down to about 500 r. p. m. With this small sized pump some clogging occurred, from the large amount of hair in the sludge. The sludge was, therefore, passed into the sludge reservoir through a screen of 4 meshes to the linear inch.

Sludge was supplied to the pump from 50 gal. barrels through a 1½ in. pipe line. In order to maintain a uniform pressure inside the press, a bypass around the pump was provided, in which was set a safety valve of the ball and lever type, and a check valve was inserted in the force main. When the desired pressure was attained in the press, the safety valve opened, allowing the sludge to circulate through the pump. The check valve closed until the pressure dropped sufficiently for the safety valve to close.

METHOD OF CONDUCTING EXPERIMENTS. Sludge from both plain sedimentation and chemical precipitation was used, being pumped into the press and kept under pressure for 15 to 60 min., or until the filtrate ceased to flow. The pump was then shut down, the liquid sludge inside drained out and the cake removed from the filter leaves. Samples of the original sludge, the wet sludge from the press and the cake formed on the leaves were taken for moisture analysis and a sample of the filtrate was collected for the determination of organic nitrogen, free ammonia and oxygen consumed. The weights of the filtrate and sludge cake were also recorded. Frequent readings of the pressure gauge were made.

In a few experiments the draining of the wet sludge from the press was followed by the application of compressed air in the attempt to still further reduce the moisture content in the sludge cake. Owing to the small size of the compressor available (2½x3 in.), uniform pressure could not be maintained in the air tanks (capacity 10.4 cu. ft.). They were filled to about 22 lb. per sq. in. gage and then discharged till the pressure had dropped to 5 or 6 lb. Part of the runs were made in duplicate and part as individual tests.

RESULTS. In the individual experiments (table 69), the sludge varied considerably in moisture content, running between 90.1 and 98.7 per cent., or somewhat higher than in the tanks. In 2 minutes time the press was filled and put under pressure ordinarily between 70 and 80 lb. per sq. in. At pressures exceeding 90 lb., it was found impossible to make the press watertight around the gasket. In general with most sludges, about 15 min. was required for one cycle after the working pressure had been reached, the amount of water removed thereafter being insignificant in amount on account of the gradual clogging of the sludge cake. Hence most of the tests were made in approximately 15 min. The sludge used in test No. 3 was exceedingly thin, the run extending over one hour before clogging became pronounced. In fact this sludge was so thin that in attempting to run a second test with it, complete failure resulted, as the pressure apparently distended the filter bags sufficiently to pass the thin sludge through practically unchanged.

At the conclusion of the cycle, the liquid sludge was withdrawn, the press opened, and all the sludge adhering to the filter leaves was treated as sludge cake. This cake ordinarily averaged about ½ in. thickness, being moist and sticky on the outside with a drier layer adjacent to the filter leaves. When compressed air was applied at the rear of the press after the withdrawal of the liquid sludge, the additional water forced out varied from 2.8 to 12.5 per cent. of the total volume accumulated. The initial air pressure varied from 20 to 23 lb. per sq. in., dropping to a final pressure of 5 or 6 lb. per sq. in. In general the sludge cake treated with air appeared slightly drier than that resulting from pressing alone.

Irrespective of the initial moisture content, a reduction to about 75 per cent. moisture, figured on the wet basis, was in general secured. Although most air dried sludges may be readily handled at a moisture content no lower than this, the sludge cake removed from the press was uniformly too sticky to be readily handled, even though much firmer than the original wet sludge. The greasy slimy nature of the sludges employed interfered with the efficiency of the process. A subsequent short period of air drying would probably suffice to make the pressed sludge fit for handling, although adding to the expense of treatment. Higher pressures both in pressing and in air treatment, subsequent to pressing, might increase the efficiency of the process. However, continuous rehandling of the liquid sludge remaining in the press at the end of a cycle is troublesome. Moreover, some of the wet sludge adheres to the filter leaves, thus increasing the moisture content of the cake. A press with chambers in the form of thin flat cells, treating all sludge pumped

TABLE 69.

SLUDGE PRESSING.

Weight of Sludge Pressed and Moisture Reduction.

Designation		Source of Sludge	Pressure Applied		Weight in Pounds				Per Cent Moisture			Compressed Air	
							Original Sludge		Wet Basis				
Test	Run		Lb. per Sq. In.	Time in Min.	Filtrate	Sludge Cake	Total	Per Sq. Ft.	Original Sludge	Wet Press Sludge	Sludge Cake	Vol. Cu. Ft. Free Air	Range in Press. Lb. Sq. In.
2	1	P. S.	64	15	8.56	3.06	11.62	5.81	89.7	91.5	75.0	0	......
2	2	P. S.	74	13	5.41	1.81	7.22	3.61	....	....	....	0	......
3	1	P. S.	59	57.5	45.10	8.75	53.85	26.93	98.7	98.7	75.2	12.1	22 to 5
4	1	C. P.	79	11.5	6.11	1.56	7.67	3.84	91.0	91.2	73.5	19.9	23 to 6
5	1	C. P.	71	16.5	7.42	2.34	9.76	4.88	....	91.7	75.0	8.5	21 to 8
6	1	C. P.	76	16.5	6.81	1.91	8.72	4.36	93.3	92.8	76.4	9.2	20 to 7
7	1	P. S.	74	16	9.02	4.22	13.24	6.62	96.1	95.4	77.1	13.9	22 to 2
7	2	P. S.	69	15.5	9.26	4.25	13.51	6.76	....	....	80.1	0	......
8	1	P. S.	69	16	22.60	8.03	30.63	15.32	95.1	93.1	79.5	0	......
8	2	P. S.	56	10	26.40	4.97	31.37	15.69	....	....	....	0	......
9	1	C. P.	51	16	5.31	3.06	8.37	4.18	90.8	90.1	75.5	0	......
9	2	C. P.	53	16	5.31	2.75	8.06	4.03	....	....	....	0	......
Average	....	....	66	18.5	13.11	3.89	17.00	8.47	93.5	93.1	76.4	....	......

Abbreviations:

P. S.—Plain sedimentation.
C. P.—Chemical precipitation.

in during a cycle without rehandling would seem more economical of time and power.

Slight differences appear in the moisture content of the original sludge and wet sludge from the press (table 69), which are probably errors in sampling and analysis rather than a real change in the composition of the sludge.

Assuming the entire filtrate to come from the sludge cake remaining on the filter leaves, and adding the weight of the sludge cake and filtrate, the weight of the original sludge treated is obtained. With a total effective area in filter leaves of 2.0 sq. ft., the sludge treated during one cycle varied from 3.61 to 26.92 lb. per sq. ft. of filter area. In general from 4 to 7 lb. was handled, however, the maximum yield being obtained from a sludge exceptionally high in moisture. Assuming that one cubic yard of sludge weighs 1740 lb. (sp. gr. 1.03), this would represent treatment at the rate of from 0.0021 to 0.0155 cu. yd. per sq. ft. per cycle. Under the conditions obtaining, about 15 min. were required for actual pressing. Hence at least 30 min. appear necessary for all operations incidental to a complete cycle, and 16 cycles might be made in an 8-hr. day with no allowance for repairs, shut-downs, etc. This would produce a rate of from 0.034 to 0.25 cu. yd. per sq. ft. per day of 8 hr.

TABLE 70.

ANALYSES OF FILTRATE FROM SLUDGE PRESS.

Test No.	Date 1913 Oct.	Parts Per Million			Source of Sludge
		Organic Nitrogen	Free Ammonia	Oxygen Consumed	
3	14	9	71	...	Plain Sedimentation.
4	16	103	241	138	Chemical Precipitation.
5	17	62	218	135	Chemical Precipitation.
6	18	18	278	125	Chemical Precipitation.
7	20	24	81	114	Plain Sedimentation.
8	23	34	96	145	Plain Sedimentation.
9	24	22	128	121	Chemical Precipitation.

The filtrate was light yellow in color and somewhat odorous. The analyses (table 70) show a content high in organic nitrogen and oxygen consumed, and exceedingly high in free ammonia. In a system of treatment including sprinkling filters, the sludge press filtrate might be discharged into the tank effluent for treatment on the filters.

A few analyses of the press cake are as follows:

ANALYSES OF SLUDGE CAKE

Source of Sludge	Specific Gravity	Per Cent Moisture	Dry Basis—Percentage			
			Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble
Dortmund	1.03	80.0	3.00	69	31	10.7
Dortmund	1.05	79.4	2.92	73	27	10.4
Chem. Precip.	1.07	75.8	2.00	58	42	5.7

The sludge pressing experiments were somewhat disappointing, as the cake produced could not be readily handled, although the moisture content was materially reduced. However, either higher pressures or a somewhat different type of press, or both might modify these results.

SLUDGE VALUES.

FERTILIZING VALUE. To learn the probable value of the sludge as a base for fertilizer, four samples were submitted to Mr. W. D. Richardson, the Chief Chemist of Swift & Co., with the results shown in table 71.

The grit chamber sludge was fresh, while the other samples had been submitted to protracted periods of air drying on the sludge beds, on the ground and at the 39th St. pumping station. Some mineralization of volatile constituents took place during this period of drying, but the loss of nitrogen was slight.

The results of these analyses were not very promising. Despite the high content of organic matter in the Stockyards sludge, the nitrogen was not exceptionally high in amount and the other essential manurial elements were not present in sufficient quantities to make their recovery very practical from a commercial standpoint. Mr. Richardson stated that the sludges did not appear to have any great commercial value as a base for fertilizer. He did, however, mention the possibility of using a product, dried and ground, as a filler for higher grade fertilizers. Any attempt to use the sludge either as a base or filler would, of necessity, require a greater degree of dryness than is attained even after protracted periods of air drying. If a residual moisture content of 15 per cent. is requisite for bagging, mechanical drying would be required. It is questionable whether the increased cost of such drying would be offset by the value of the material as a fertilizer. The high grease content also renders the dried sludge unsuitable for fertilizing purposes, unless extracted. With artificial drying and extraction of the fat, it is possible that this material can be utilized.

TABLE 71.

SLUDGE DISPOSAL.

Analyses of Sludge for Fertilizing Value

Source	Percentages				
	Moisture	Phosphoric Acid	Nitrogen	Ammonia	Potash Sol. in Water
FIGURED TO SLUDGE AS SUBMITTED					
Grit Chamber......	32.8	3.12	0.72	0.88	....
Dortmund Scum. .	56.6	0.72	1.00	1.22	....
Dortmund Sludge . .	26.0	0.76	1.17	1.42	....
Emscher Scum.....	47.7	0.74	1.32	1.60	....
FIGURED TO DRY BASIS					
Grit Chamber......	....	4.64	1.08	1.31	0.03
Dortmund Scum. . .	....	1.65	2.30	2.80	0.08
Dortmund Sludge . .	....	1.03	1.57	1.91	0.06
Emscher Scum	....	1.42	2.52	3.06	0.09

CALORIFIC VALUE. The possibility of developing the heat values in the volatile constituents of sewage sludge in a practical way has been studied by many. In this case, owing to the exceptionally high content of volatile matter, the determinations of heat values were of unusual interest. Nine samples were submitted to the Gulick-Henderson Co. for B. T. U. analysis, at different times, the source, condition and serial numbers being as follows:

SLUDGES FOR B. T. U. ANALYSIS.

Number. Source and Condition.

1. Grit chamber;—fresh sludge.
2. Emscher tank;—fresh sludge.
3. Dortmund tank (C);—fresh sludge after filter pressing.
4. Chemical precipitation;—fresh sludge after filter pressing.
5. Dortmund tank (D);—scum after air drying 90 days.
6. Dortmund tank (D);—sludge after air drying 100 days.
7. Emscher tank;—scum after air drying 80 days.
8. Emscher tank;—sludge after air drying 23 days.
9. Rotary screen;—fresh screenings.

The chemical analyses of the fresh and air dried sludges (table 72) show that the air dried sludges have all lost a portion of volatile constituents. The moisture content was materially reduced. In table 73 are given the B. T. U. analyses of the samples noted in table 72, with the percentage of volatile constituents and moisture at the time of analysis. On the dry basis, the calorific value of the sludges varies almost directly with the amount of volatile matter, suggesting the desirability of drying fresh sludge as rapidly as possible to obtain the full thermal value, without loss of volatile matter. The

TABLE 72.

SLUDGE DISPOSAL.

Analyses of Sludge for B. T. U. Determinations.

Serial No.	Spec. Grav.	Per Cent Moist.	Calculated to Dry Weight Percentage				Remarks
			Nit.	Vol. Matter	Fixed Matter	Ether Sol.	
			ORIGINAL SLUDGE				
1	1.13	55.4	0.88	39.8	60.2	2.8	Grit chamber sludge.
2	1.02	85.3	2.96	72.9	27.1	4.4	Emscher sludge.
3	....	96.1	3.00	70.6	29.4	10.6	Dortmund sludge.
4	....	90.1	2.00	56.8	43.3	5.5	Chemical precip. sludge.
5	1.01	81.3	3.36	74.0	26.0	10.4	Dortmund scum.
6	1.00	95.8	2.32	69.5	30.5	8.6	Dortmund sludge.
7	1.03	79.3	2.56	73.1	26.9	....	Emscher scum.
8	1.02	91.8	2.73	56.5	43.5	6.3	Emscher sludge.
9	....	85.5	3.00	93.5	6.5	6.6	Rotary screenings.
			AT TIME OF B. T. U. ANALYSIS				
3	1.03	80.3	3.00	70.6	29.4	10.6	After pressing.
4	1.07	75.6	2.00	56.8	43.2	5.5	After pressing.
5	....	53.4	2.96*	69.8*	30.2*	8.5*	After air drying.
6	....	24.1	2.56*	41.1*	58.9*	....	After air drying.
7	....	47.3	2.16*	60.9*	39.1*	5.5*	After air drying.
8	1.09	76.1	2.92	54.8	45.2	4.8	After air drying.

* About one month before B. T. U. Analyses.

fresh Dortmund tank sludges contain more heat units than the well-digested Emscher tank sludge. The difference between Emscher sludges numbers 2 and 8 is interesting. The former represents a sample taken before digestion had become established. The latter was collected, after the tank had become thoroughly ripened, and was air dried for a few days. The reduction in heat value is considerable. The chemical precipitation sludge with its high content of inert mineral matter is lower in calorific value than the other fresh sludges. The heat values on the dry basis, in general, exceed the figures obtained on the 39th St. sludges from similar tanks, when handled under substantially the same conditions. The higher content of volatile matter at the Stockyards is doubtless responsible for this.

Foreign experiments indicate that sludges containing 60 per cent. of moisture can be burned under forced draft without the use of additional fuel. As the fresh sludges from the Stockyards sewage are considerably higher in volatile matter than those derived from ordinary sources, incineration should prove correspondingly more successful. The high initial moisture content is the chief obstacle to disposal in this manner. As a basis for comparison, a residual moisture content of 50 per cent. may be assumed; then

TABLE 73.

SLUDGE DISPOSAL.

Results of B. T. U. Analyses.

Serial Number	Per Cent Moisture		B. T. U. per Pound				Per Cent Volatile Matter at Time of Analysis	Remarks
	At Time of Analysis	As Analyzed	Dry Sludge	At Time of Analysis	Theoretical Available Time of Analysis	Theoretical Available 50 per Ct. Moisture		
1	55.4	31.99	3,408	1,520	898	1,149	39.8	Fresh grit chamber sludge.
2	85.3	3.52*	8,220	1,190	235	3,551	72.9	Fresh Emscher sludge.
3	80.3	3.43*	9,109	1,795	898	3,996	70.6	Fresh Dortmund sludge after pressing.
4	75.6	4.67*	5,345	1,305	460	2,114	56.8	Fresh Chem. Pre. sludge.
5	53.4	53.44	6,267	2,920	2,323	2,575	69.8†	Dortmund scum after air drying.
6	24.1	24.12	2,475	1,880	1,610	....	41.1†	Dortmund sludge, after air drying.
7	47.3	47.31	5,805	3,060	2,531	....	60.9†	Emscher scum, after air drying.
8	76.1	3.75*	5,799	1,386	535	2,340	54.8	Emscher sludge, after air drying.
9	85.5	6.15*	9,078	1,315	360	3,980	93.5	Fresh rotary screenings.

* Artificially dried.
† About one month before B. T. U. analyses.

taking 1118 B. T. U. as the amount of heat required to raise one pound of water from 60 deg. to 212 deg. Fah. and convert it into steam, the theoretical available heat units were computed, as well as the theoretical available heat units with the actual moisture content at the time of analysis. On the former basis, the fresh, undigested Emscher sludge, the fresh Dortmund sludge and the fresh screenings show values approaching 4000 B. T. U. per pound. The air dried Dortmund sludges and scums, the digested Emscher sludge and the fresh chemical precipitation sludge, with the lower content of volatile matter, show considerably smaller values, while the fresh grit chamber sludge with its initially high percentage of inert mineral matter is even lower still. Figured on the original moisture content, the number of heat units required to evaporate the moisture contained in the fresh sludges reduces the available calorific value to insignificant proportions. Even though allowance is made for the heat required to vaporize the contained moisture, an additional loss would probably be incurred in volatilizing the fats present, part of which would probably be permanent.

Our experience has shown that long continued periods of air drying are required, even under favorable conditions, to reduce the moisture content of the sludges to 50 or even 60 per cent., accompanied, moreover, by an appreciable loss of heat-producing constituents. To dispose of sludge by burning, rapid drying of the fresh product, therefore, appears preferable. The filter press did not reduce the moisture much below 75 per cent.

The calorific value of coal varies per pound from about 7000 B. T. U. for lignites to 12,500 B. T. U. for high grade anthracites. In comparison, therefore, the fresh sludges from plain sedimentation and the fresh screenings, with a moisture content reduced to 50 per cent., are seen to have a substantial thermal value.

Artificial drying to attain this moisture content would probably be costly from the mere utilization standpoint, but as a means of sludge disposal it may prove economical some day. Our results indicate the theoretical heat units available, whereas in actual operation, less would be effective as an efficiency of 100 per cent. would not be obtained under a boiler. Ordinarily, with coal, an efficiency from 50 to 65 per cent. is secured, and a correction, unknown but considerable, would therefore be necessary in applying these sludge figures. Special grates and furnaces would probably be required. A considerable volume of residue or ash would accumulate, much less, however, than the original sludge. If the sludge is properly burned, however, this residue should be entirely inoffensive in character, and would be suitable for filling.

CHAPTER XI.

SCREENING.

COARSE SCREEN.

RESULTS. The coarse screen protecting the pump was made of ⅝ in. round bars set to give a ⅝ in. clear opening, and inclined at an angle of 30 deg. with the horizontal in the direction of flow. It was 9⅜ in. wide, with a gross area of 1.43 sq. ft. below the flow line. The screen was cleaned with a rake, usually two or three times daily. The amount of screenings removed was recorded continuously, the monthly averages being given in table 74 and occasional analyses of composite samples in table 75.

TABLE 74.

COARSE SCREENING.

Amount of Material Removed by Bar Screen in Pump Well.

Date	Sewage Screened Mil. Gal.	Weight of Moist Screenings—Pounds		
		Total	Per Day	Per Mil. Gal.
1912				
Sept. 17 to 30	1.521	125	10.4	82
October	3.085	309	10.3	100
November	3.464	333	11.1	96
December	4.197	349	11.2	83
1913				
January	4.075	322	10.4	79
February	3.211	260	9.3	81
March	2.997	242	8.3	81
April	3.254	227	7.6	70
May	3.494	248	8.0	71
June	3.761	215	7.2	57
July	4.448	206	6.7	46
August	4.409	304	9.8	69
September	4.646	506	16.8	109
October	5.265	323	10.4	61
November	4.406	400	13.3	91
December	5.262	525	17.0	100
1914				
January	3.759	1068	34.4	284
February	3.232	477	17.7	148
March	3.247	154	15.0	47
April	3.508	313	10.4	89
May	5.218	439	14.1	84
Average	3.831	350	12.3	91

The material removed consisted chiefly of straw, hair, bits of meat, skin and similar material. The weight of the moist screenings varied from 60 to 75 lb. per cu. ft. The odor was usually offensive, like decayed meat. Analyses indicated a high content of organic matter and nitrogen, as well as fat. The moisture content seems large, considering the nature of the material which appeared dry and firm.

The removal was nominal, as a rule from 70 to 100 lb. per mil. gal., or as the screenings averaged about 82 per cent. moisture, from 12 to 18 lb. of dry material per mil. gal. For a testing station these results are materially different from those obtained on strictly domestic sewage, although for working plants the amounts are within the range of variations reported individually. The pipe supplying the plant leaves the main sewer about one foot above the invert, in a depth of flow around three feet. This may decrease the light floating refuse entering the pump well, and as the plant supply is

TABLE 75.

COARSE SCREENING.

Analyses of Screenings.

Date	Per Cent Moisture	Calculated to Dry Weight—Percentage			
		Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble
1912					
Sept. 17 to 22....	85.2	4.24	83.4	16.6	12.8
Oct. 5 to 11....	79.8	4.56	85.7	14.3	18.0
21 to 26....	82.0	4.56	88.8	11.2	6.9
Nov. 30 to Dec. 6	84.0	4.96	86.3	13.7	13.5
1913					
Feb. 24 to Mar. 2	78.3	4.64	79.3	20.7	13.6

diverted from the sewer at right angles to the direction of flow, the coarse material sampled thereby may be decreased also. Most of the material actually caught accumulated during the daylight hours, thus increasing the rate of accumulation during certain hours, much above the average for 24 hours. Hence, in an actual plant larger amounts of screenings would doubtless have to be handled, if coarse screening is adopted.

FINE SCREENING.

GENERAL. The large proportion of coarse fibrous material present in suspension suggested the use of fine screening. The device tried consisted of a rotary screen (cf. p. 37), covered with brass

wire cloth with 30 meshes per lineal inch, cylindrical in shape, 4 ft. 8 in. long, with an effective diameter of 2 ft. 4 in., giving a gross superficial area of 34.2 sq. ft. The area is diminished, however, by the supporting bands of iron which leave a net effective screen area of 29.3 sq. ft. The screen was revolved seven times per minute. In a screen of this type, to prevent clogging, the material caught must be kept from adhering to the screen, usually by jets of water or air. At first a ¾ in. pipe, set parallel to the axis of the screen and drilled with 1/16 in. holes, spaced 4 in. apart, was placed about 6 in. from the screen, being free to move in its supports, and connected by a flexible hose to the water line. The jets of water impinged normally on the outer surface of the screen a short distance below the top. The pipe was moved back and forth by a pair of rollers clamped to it which engaged a helical band of galvanized iron encircling the screen, bent to give a backward and forward travel of 4 in. in one revolution. This device proved very unsatisfactory, as the needle-like jets from the sprinkler pipe only covered a very small portion of the screen, and as the cycle of travel was the same as that of the screen, the jets continuously followed the same path. A stationary pipe was substituted, into which were tapped at 4-in. intervals ⅛-in. nipples, 2 in. long, flattened at the outlet end to give a fan shaped spray. To further increase the efficiency of distribution, these jets were directed against a sheet of galvanized iron bent to proper shape to deflect the spray against the screen in a continuous film. Water for cleaning was taken through a meter directly from the line supplying the testing station.

An attempt was also made to investigate the efficiency of compressed air as a cleaning agent, but the small compressor (2½ in. x 3 in.) available was totally inadequate for furnishing the necessary volume of air at the required pressure.

OPERATION. Three separate runs were made with the screen; one during the fall of 1913, when it was in operation daily from 8 A. M. to 4 P. M., one run in May, 1914, from 7:30 A. M. to 10:30 P. M., and one in July, 1914, when it was in operation between 8 A. M. and 11 P. M. For a few days on the second run, the operation was continued throughout the night.

RATE. The screen was operated at rates varying from 117,000 to 235,000 gal. per 24 hr. With a net effective area of 29.3 sq. ft., this corresponds to a rate of from 4,000 to 8,000 gal. per sq. ft. per 24 hr., or with a rotative speed of approximately 7 r. p. m. to a treatment of from approximately 0.4 to 0.8 gal. per sq. ft. of clean screen exposed. However, as the sewage did not actually reach the outlet end of the screen, the actual rate of application was somewhat higher

TABLE 76.

ROTARY SCREEN ON CENTER AVE. SEWAGE.

Reduction in Suspended Matter.

Date 1913	Suspended Matter—Parts per Million						Per Cent Reduction			Screenings as Susp. Matter P.P.M.	Computed Influent from Scrngs.	Per Ct. Reduction S. M. from Computed Influent	Remarks
	Influent			Effluent									
	Total	Volatile	Fixed	Total	Volatile	Fixed	Total	Volatile	Fixed				
Oct. 20...	360	210	150	384	187	197	7*	11	31*	62	446	14	....
21...	480	320	160	457	322	135	5	1*	16	88	545	16	....
23...	580	470	110	517	348	169	11	26	54*	130	647	20	....
24...	840	710	130	595	439	156	29	38	20*	112	707	16	....
27...	480	360	120	415	322	93	14	11	23	61	476	13	....
28...	590	490	100	526	442	84	11	10	16	102	628	16	....
29...	660	600	60	542	469	73	18	22	22*	80	622	13	....
30...	1230	1100	130	574	470	104	53	57	20	118	692	17	....
31...	1010	830	180	705	558	147	30	33	18	95	800	12	....
Nov. 3...	1070	850	220	639	440	199	40	48	10	115	754	15	....
7...	1080	900	180	687	583	104	36	35	42	125	812	15	....
11...	1310	1060	250	664	519	145	49	51	42	...	...	..	....
12...	1180	930	250	560	415	145	53	55	42	85	645	13	....
13...	800	610	190	655	457	198	18	25	4*	152	807	19	....
14...	572	416	156	518	380	138	10	9	12	118	636	19	....
17...	548	404	144	476	349	127	13	14	12	100	576	17	....
18...	600	484	116	425	317	108	29	34	7	127	552	23	....
19...	850	730	120	582	447	135	33	39	13*	170	752	23	....
Dec. 1...	880	690	190	572	426	146	35	38	23	84	656	13	....
2...	720	580	140	510	385	125	29	34	11	109	619	17	....
3...	970	740	230	652	455	197	33	39	14	161	813	20	....
4...	730	540	190	662	465	197	9	14	4*	133	795	17	....
5...	1390	1210	180	606	493	113	56	59	37	166	772	22	....
9...	770	650	120	482	410	72	37	37	40	77	559	14	....
10...	860	730	130	482	388	94	44	47	28	107	589	18	....
11...	1010	870	140	578	494	84	43	43	40	165	743	22	8 a.m. to 4 p.m.
11...	750	650	100	702	606	96	6	7	4	109	811	14	4 p.m. to 11 p.m.
Average...	827	672	155	561	428	133	32	36	14	113	671	17	

than noted above. Moreover, the longitudinal distribution was not uniform, the inlet portion handling a larger proportion of the sewage.

The high rate stated was the maximum obtainable with the apparatus at hand, and might have been increased somewhat without detriment to the efficiency of operation, until a point was reached where the amount of water or other cleaning agent became disproportionate. Increasing the rotative speed would also increase the capacity of the screen to a certain extent. However, a limit would be reached from mechanical reasons and also because of the possible tendency to excessive clogging at the bottom of the screen due to large amounts of material removed at high rates dropping back to the bottom by the cleaning device. Finally the head required to force the liquid through the screen combined with the clogging effect of the material removed might become excessive at high rates.

PERCENTAGE REMOVAL OF SUSPENDED MATTER. Tables 28, 29 and 76 show the content of suspended matter in influent and effluent, together with the percentage reductions. For the 1913 run, both influent and effluent samples were collected, but on the 1914 runs, effluent samples only were taken and the influent analyses were computed by adding the weight of dry screenings collected as p. p. m. The percentage removals based on actual analyses are somewhat erratic, varying from an apparent increase of 7 per cent. to a decrease of 53 per cent. The increase was not real, as an actual reduction always takes place, the reduction being greater with the sewage containing the most suspended matter. Discrepancies of this sort, as well as some of the fluctuation in results, are due to errors of sampling and analysis. In general, the reduction in volatile matter was greater than the decrease in fixed matter.

As the comparatively large particles removed by the screen are not well represented in the analyses, additional columns show, for the first run, the screenings removed figured as parts per million and a computed analysis of the influent based on the combined screenings and effluent. The percentage reductions, figured on this basis, show considerably less fluctuation in individual cases, and usually run somewhat below those obtained by the actual analyses. However, they probably represent the actual conditions obtaining more accurately. From the actual analyses, during the first run, an average reduction of about 32 per cent. was obtained in 27 experiments, while the computed analyses gave an average reduction of 17 per cent. Extending the period of operation into the evening, as was done on the second and third runs, reduced the average removal to about 12 per cent., based on computed analysis. The strength

of the sewage falls off during the evening and lower average efficiencies are thus to be expected by extending the period.

CHARACTER OF SCREENINGS. The material removed by the screen was a dirty yellow color, and consisted largely of hay, chaff, paunch manure, undigested food particles, hair, bits of skin and flesh and similar materials. The composition was largely organic, the proportion of volatile matter uniformly exceeding 90 per cent. on the dry basis, with a nitrogen content higher than in the tank sludges and a high fat content. Occasional analyses are given (table 77).

TABLE 77.

ANALYSIS OF SCREENINGS FROM 30 MESH ROTARY SCREEN.

Date	Per Cent Moisture	Dry Weight—Percentage			
		Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble
1913					
Oct. 28.........	84.8	2.72	93	7	7.4
Oct. 29*........	85.4	3.00	94	6	6.6
Oct. 30*........	82.9	3.36	90	10	8.2
Nov. 19.........	87.2	3.68	98	2	14.0
Dec. 1.........	87.0	4.48	97	3	8.4
9.........	90.9	....	91	9	....

* Average of 2 analyses.

The material when fresh was entirely inoffensive, in odor and appearance. On standing in layers 5 or 6 in. thick, a very disagreeable putrid odor soon developed, considerable heat being generated in the interior of the mass. The screenings were discharged from the screen, firm enough to shovel, although comparatively high in moisture. The fibrous character of the material removed apparently favored the retention of water, for when spread out in thin layers on the ground, the screenings dried rapidly at the surface to a fibrous mass, but the deeper layers retained a considerable portion of their initial moisture. A sample removed from the screen on Dec. 1, 1913, and placed in a box on the roof of the screen-house to a depth of 6 in., with an initial moisture content of 87 per cent., showed an average moisture content of 70 per cent. at the end of two weeks. The box in which it was exposed was practically watertight, so that water was lost only by evaporation. During this period more or less damp, cold, rainy weather retarted drying. Nevertheless, the surface material reduced to a dry crumbly mass, the interior layers being somewhat moist, however. Under favorable

TABLE 78.

ROTARY SCREEN ON CENTER AVE. SEWAGE.

Results of Run on Screen when Operated Between 8 A. M. and 4 P. M. in 1913.

Date, 1913	Rate Gallons per 24 Hours	Period Run Hours	Gallons Screened	Screenings Per Cent Moisture	Screenings Lb. per Million Gallons		Moist Screenings Lb. per Cu. Ft.	Wash Water		Remark
					Moist	Dry		Per Cent	Gal. per Lb. Dry Screenings	
Oct. 20	155,200	4.5	29,200	81.6	2,800	515	....	3.46	67	....
21	156,800	7.3	47,900	83.6	4,470	735	....	3.71	47	....
23	194,000	7.0	56,600	83.3	6,450	1,080	....	5.42	51	....
24	193,500	7.5	60,500	81.3	5,000	935	....	4.55	49	....
27	232,800	8.0	67,900	83.3	3,020	505	....	3.88	77	....
28	232,200	6.0	77,400	84.8	5,550	845	....	5.08	60	....
29	231,000	6.5	57,800	85.5	4,570	665	....	4.25	64	....
30	240,000	8.0	65,000	82.9	5,770	985	....	4.33	44	....
31	232,800	7.0	77,600	87.0	6,100	795	....	5.09	64	....
Nov. 3	232,500	8.0	67,800	86.6	7,150	960	62.1	4.70	49	....
7	234,000	8.0	78,000	89.1	9,580	1,045	....	4.08	39	....
12	235,000	8.0	78,400	89.3	6,590	705	63.1	3.80	52	....
13	234,000	8.0	78,000	88.7	11,100	1,265	61.0	3.66	30	....
14	234,600	8.0	78,200	88.5	8,540	980	63.3	4.44	45	....
17	234,000	7.2	70,000	87.3	6,530	830	63.3	4.46	54	....
18	234,000	6.0	58,500	87.6	8,530	1,060	64.0	4.26	40	....
19	234,000	1.2	11,300	87.2	11,500	1,420	63.9	3.98	28	....
Dec. 1	234,000	7.0	68,300	87.0	5,400	700	63.9	4.03	58	....
2	234,000	8.0	78,000	88.7	8,030	910	63.9	4.03	44	....
3	234,000	8.0	78,000	87.6	10,850	1,345	63.9	3.54	26	....
4	234,000	8.0	78,000	88.9	9,380	1,110	63.9	3.37	30	....
5	234,000	8.0	78,000	86.5	11,750	1,385	63.7	2.83	20	....
9	234,000	8.0	78,000	90.9	7,080	645	63.9	2.56	40	....
10	234,000	6.4	62,600	86.5	6,600	890	63.9	4.68	53	....
11	234,000	8.0	78,000	86.7	10,400	1,380	62.9	4.99	36	....
Average	224.500	7.1	66,300	86.4	7,300	950	63.5	4.13	47	

TABLE 79.

ROTARY SCREEN ON CENTER AVE. SEWAGE.

Results of Run on Screen in May, 1914.

Date May, 1914	Rate Gallons per 24 Hours	Day Sewage 7:30 A. M. to 10:30 P. M. Hours Operated	Gallons Screened	Screenings Per Ct. Moist.	Screenings Lb. per Mil. Gal.		Moist Screen. Lb. per Cu. Ft.	Per Cent Wash Water	Night Sewage 10:30 to P. M. 7:30 A. M. Hours Operated	Gallons Screened	Screenings Per Ct. Moist.	Screenings Lb. per Mil. Gal.		Moist Screen. Lb. per Cu. Ft.	Per Cent Wash Water
					Moist	Dry						Moist	Dry		
1	117,000	8.0	39,000	84.0	3,010	482	....	7.75	0	......	....	...	..	....	....
2	117,000	15.0	73,100	80.1	2,540	505	....	7.49	0	......	....	...	..	....	....
3	Sunday.	Not run	......	....	....	...	....	....	...	......	....	...	..	....	....
4	117,000	13.6	66,400	81.9	4,500	816	51.2	6.06	0	......	....	...	..	....	....
5	117,000	15.0	73,100	82.2	2,390	426	53.2	6.60	0	......	....	...	..	....	....
6	119,100	15.0	74,500	82.4	2,440	430	55.4	4.50	0	......	....	...	..	....	....
7	118,000	8.3	40,800	82.4	2,700	475	52.6	5.39	0	......	....	...	..	....	....
8	116,500	12.5	60,600	80.9	1,920	367	40.0	4.30	0	......	....	...	..	....	....
9	117,000	8.2	40,000	82.5	3,600	630	60.8	5.87	0	......	....	...	..	....	....
10	Sunday.	Not run	......	....	....	...	....	....	...	......	....	...	..	....	....
11	117,000	15.0	73,100	78.1	1,890	414	47.3	3.46	0	......	....	...	..	....	....
12	117,000	15.0	73,100	82.7	1,750	304	41.4	3.35	0	......	....	...	..	....	....
13	117,000	15.0	73,100	83.4	2,810	466	50.7	4.34	0	......	....	...	..	....	....
14	117,000	15.0	73,100	83.0	2,530	430	47.2	4.63	0	......	....	...	..	....	....
15	117,000	15.0	73,100	81.8	2,700	458	44.8	4.52	0	......	....	...	..	....	....
16	117,000	11.5	56,100	77.7	1,730	385	41.1	5.26	0	......	....	...	..	....	....
17	Sunday.	Not run	......	....	....	...	....	....	...	......	....	...	..	....	....
18	117,000	14.0	68,300	81.2	3,100	584	51.6	3.18	9.0	43,800	81.2	217	41	47.5	6.03
19	117,000	15.0	73,100	75.5	2,460	603	46.6	2.38	9.0	43,800	77.3	114	26	55.5	2.40
20	117,000	15.0	73,100	82.5	2,800	490	52.8	3.12	9.0	43,800	82.3	194	34	53.2	3.70
21	117,000	15.0	73,100	80.6	2,870	555	51.3	3.28	9.0	43,800	82.9	137	23	54.5	2.68
22	117,000	15.0	73,100	79.3	1,660	342	48.7	2.76	9.0	43,800	81.6	183	34	47.2	3.39
23	117,000	9.2	44,800	77.5	1,600	359	39.5	3.17	0	......	....	...	..	....	....
24	Sunday.	Not run	......	....	....	...	....	....	...	......	....	...	..	....	....
25	117,000	15.0	73,100	80.9	2,680	512	47.6	3.18	0	......	....	...	..	....	....
26	117,000	15.0	73,100	78.1	2,610	573	45.4	3.47	0	......	....	...	..	....	....
27	117,000	15.0	73,100	81.9	3,990	722	50.0	4.80	0	......	....	...	..	....	....
28	117,000	15.0	73,100	78.5	3,050	655	44.0	2.37	0	......	....	...	..	....	....
29	117,000	15.0	73,100	80.6	2,700	524	....	2.70	0	......	....	...	..	....	....
30	Holiday.	Not run	......	....	....	...	....	....	...	......	....	...	..	....	....
31	Sunday.	Not run	......	....	....	...	....	....	...	......	....	...	..	....	....

weather conditions, if spread in thin layers and turned at intervals to expose the under layers to the action of the sun and air, rapid drying should ensue, and the remaining residue could be disposed of by burning. Some odor might occur, as putrefactive conditions tend to develop rapidly in the moist mass . The volatile constituents were reduced during the drying period, the original sample containing 97 per cent. of volatile matter and the dried sample 87 per cent.

AMOUNT OF MATERIAL REMOVED. Tables 78, 79 and 80 show the amount of material removed both as pounds of moist screenings per million gallons and as pounds of dry material for the same unit for the three runs. The screenings were shoveled from the discharge trough into the weighing can during the first run and were slightly drier than as actually discharged. On the second and third runs they fell into a perforated can, the surplus moisture draining away. Nevertheless, they were readily handled, considering the high moisture content, ranging between 85 and 89 per cent.

On the wet basis, from 3,000 to 12,000 lb. of moist screenings per mil. gal. of sewage may be expected during the hours of heavy flow. Extending the run into the evening hours reduced the amount to from 1000 to 4500 lb. per mil. gal. Seasonal variations in strength of sewage and fluctuations in moisture content of the screenings may account for some of the difference observed. Reduced to the dry basis, these figures range from about 500 to 1400 lb. per mil. gal. for the first run, and from about 194 to 815 lb. for the second and third.

The unit weight of material varied somewhat (tables 78, 79 and 80) according to the degree of draining and compacting, but in general the specific gravity of the material as discharged slightly exceeded unity, showing that a portion at least will settle under nearly quiescent conditions. On the second and third runs the material was more thoroughly drained and consequently more porous than on the first, and the unit weights were correspondingly lower. From 85 to 184 cu. ft. of moist screenings were removed per mil. gal. during the first run.

As a remedy for excessive scum formation on settling tanks, the use of fine screens was suggested herein (cf. p. 66). It also seems desirable to reduce the amount of sludge to be handled, as the moist screenings are more easily cared for than the liquid sludge. Dry screenings at the rate of 500 lb. per mil. gal. represent a retention of about 3 cu. yd. of 90 per cent. sludge or 2 cu. yd. of 85 per cent. scum.

CLEANING. Water from the city main was used, at a very

TABLE 80.

ROTARY SCREEN ON CENTER AVE. SEWAGE.

Results of Run on Screen in July, 1914.

Date July, 1914	Day Sewage, 8 A. M. to 11 P. M.								Remarks
	Rate Gallons per 24 Hours	Hours Operated	Gallons Screened	Screenings Per Cent Moisture	Screenings, Lb. per Million Gallons		Moist Screenings Lb. per Cu. Ft.	Per Cent Wash Water	
					Moist	Dry			
6	117,000	6.7	32,600	73.5	1,840	488	41.1	1.75	....
7	117,000	14.6	71,200	80.9	1,935	369	41.1	8.08	....
8	117,000	15.0	73,100	78.7	2,130	454	42.7	6.25	....
9	117,000	15.0	73,100	82.5	1,470	257	40.7	4.68	....
10	117,000	15.0	73,100	80.0	1,190	238	41.2	3.08	....
11	117,000	15.0	73,100	76.9	1,360	314	39.9	3.15	....
12	Sunday. Not run		......	....	....	...	....	....	....
13	117,000	15.0	73,100	81.6	1,130	208	46.2	2.11	....
14	117,000	15.0	73,100	81.5	1,135	210	44.4	2.55	....
15	117,000	15.0	73,100	80.5	1,530	298	48.1	3.07	....
16	117,000	15.0	73,100	75.5	1,395	342	40.8	1.62	....
17	117,000	15.0	73,100	79.0	1,715	360	40.0	3.13	....
18	117,000	15.0	73,100	77.2	1,000	228	39.7	2.07	....
19	Sunday. Not run		......	....	....	...	....	....	....
20	117,000	15.0	73,100	81.4	1,040	194	41.7	2.24	....
21	117,000	15.0	73,100	80.7	1,355	262	41.1	7.07	....
22	Lost	....	......	....	....	...	....	....	....
23	117,000	15.0	73,100	82.8	1,675	289	42.0	3.93	....
24	117,000	15.0	73,100	78.8	1,360	289	43.8	6.76	....
25	117,000	11.5	56,000	73.2	1,525	410	42.5	3.80	....
26	Sunday. Not run		......	....	....	...	....	....	....
27	117,000	15.0	73,100	79.8	2,020	408	44.5	3.25	....
28	117,000	15.0	73,100	76.9	1,810	420	40.0	5.70	....
29	117,000	15.0	73,100	78.3	1,340	291	41.8	3.10	....
30	117,000	15.0	73,100	79.2	1,830	382	45.8	4.02	....
31	117,000	15.0	73,100	81.3	1,700	317	....	4.01	....
Average....	117,000	14.5	70,400	79.1	1,520	319	42.3	3.88	

low pressure, ranging from 8 to 23 lb. per sq. in. This proved sufficient from the dynamic standpoint, moreover the water appeared to act as a lubricant, giving the screenings sufficient momentary fluidity to fall away from the screen of their own weight. The amount used varied between 2.6 and 6.4 per cent. of the volume of sewage treated for the first run. Four per cent. may be taken as a fair average value under conditions prevailing. On the second run slightly larger percentages were used, as the quantity of sewage handled was smaller. A certain minimum quantity is apparently required. In regulating the application of water, sufficient cleaning was produced to pass all the sewage through the screen before reaching the last 5 or 6 in. of screen. A fixed minimum amount of water being necessary to keep the screen free from clogging, the water consumption proved greater per pound of dry screenings for low rates of accumulation than for high. In fact the volume of water per pound of dry screenings varied roughly in inverse ratio to the rate of retention of solids. Possibly economy in water consumption might be secured by a traveling device similar to the arrangement first tried, covering various parts of the screen intermittently, but any intermittency in operation should be of very brief duration.

The efficiency of compressed air as a cleaning agent was not investigated on this rotary screen, but its utility was demonstrated in the tests made on the Jennings screen. No figures are available to show the relative economy of water and air as cleaning agents. The use of screened or settled sewage may serve to reduce the cost of water required, but clogging suspended matter might interfere.

INDUSTRIAL TESTS.

ADDITIONAL SCREENING TESTS. In October and November, 1913, additional working tests were made (1) at the outlet of the Morgan St. sewer on a traveling band screen designed by Mr. C. A. Jennings of the Union Stockyards and Transit Co. and (2) on a Weand screen installed at the packing house of Sulzberger and Sons.

DESCRIPTION OF SCREENS. The Jennings screen is of the endless band type, consisting of 38 panels, each 1 by 4 ft., framed of light structural shapes, joined at the ends to endless link chains which pass over toothed wheels supported on inclined trusses set in a pit to which the sewage is delivered. The screen was driven at a linear speed of about 125 ft. per min., and was inclined at an angle of about 30 deg. with the horizontal in the direction of flow, receiving sewage from a fan-shaped trough designed to give even

distribution. The panels were covered with 40 mesh Monel metal wire screening, supported on heavy ½ in. mesh screens, the total net screen area being 112.0 sq. ft. As the panels passed over the top pair of toothed wheels, the screenings were blown off into a pit. Compressed air under high pressure was used at the time the tests were made, being distributed by a finely perforated pipe underneath the screen, but owing to the rapid destruction of the wire mesh, a low pressure blower has since been installed, with better results.

The screen at the Sulzberger plant was of the conical Weand type, 4 ft. in diameter at the inlet end, 3 ft. at the outlet end, and 6 ft. 8 in. long over all, rotated by a central shaft at a speed of 16 r. p. m. Iron bands bolted together maintained the conical shape, the 40 mesh screen being supported on a heavy 1⅜ in. mesh screen. Screenings are ejected by a double worm around the inside of the cone. The total effective screen area is 53.3 sq. ft. Parallel to the screen was a header containing 22 petcocks with ⅛ in. openings discharging compressed air for cleaning.

SEWAGE. The Jennings screen handled drainage from a portion of the stockyards proper. This sewage was cooler (55 deg. F.) and considerably weaker than the usual packing house waste, becoming much weaker during the afternoon with the completion of the watering of cattle and cleaning up the pens for the day. Average analyses are as follows:

ANALYSES OF MORGAN ST. SEWAGE.

Determination.	Parts per Million.
Organic Nitrogen as N	15
Free Ammonia as N	11
Oxygen Consumed	103
Suspended Matter—Total	340
Volatile	260
Fixed	80

The Sulzberger screen handled the combined waste from practically the entire plant, representing a typical strong packing-house sewage, with a temperature of 89 deg. F. Average analyses are as follows:

ANALYSES OF EFFLUENT FROM SULZBERGER PLANT.

Determination.	Parts per Million.
Organic Nitrogen as N	82
Free Ammonia as N	18
Oxygen Consumed	305
Suspended Matter—Total	717
Volatile	624
Fixed	93

RATE. The Jennings screen received the entire flow from the Morgan St. sewer and was tested during the day hours when the flow was strongest, table 82 giving the average rate during individual runs. Based on a linear speed of 125 ft. per min., these figures correspond to rates of from 2.11 to 2.71 gal. per sq. ft. of clean screen area exposed.

The screen at the Sulzberger plant was run during the heavy day hours also, the rate of application being limited largely by the capacity of the device for measuring the sewage. Table 82 gives the rates at which individual tests were made. At a speed of 16 r. p. m., with a net screen area of 53.3 sq. ft., these figures reduce to rates of from 0.62 to 0.74 gal. per sq. ft. of clean screen exposed. With adequate cleaning devices this rate could undoubtedly be increased.

TABLE 81.

REMOVAL OF SUSPENDED MATTER.

Date 1913	Suspended Matter—Parts Per Million										
	Influent				Effluent			Per Cent Reduction			
	Total	Vol.	Fixed	Total Computed	Total	Vol.	Fixed	Total	Vol.	Fixed	Total Computed
JENNINGS SCREEN											
Oct. 23	310	230	80	296	170	100	70	45	57	12	43
24	440	390	50	353	240	160	80	45	59	60*	32
Nov. 4	440	290	150	523	410	260	150	7	10	0	22
5	208	152	56	350	180	136	44	14	11	21	49
19	300	236	64	400	288	216	72	4	9	12*	28
Average	340	260	80	384	257	174	83	24	33	4*	33
SULZBERGER SCREEN											
Oct. 22	520	410	110	488	450	350	100	14	15	9	8
23	800	650	150	878	540	430	110	33	34	27	39
27	620	550	70	655	540	420	120	13	24	42*	18
28	840	750	90	809	550	440	110	34	41	22*	32
29	810	760	50	966	700	640	60	14	16	20*	28
30	800	730	70	908	710	620	90	11	15	29*	22
31	630	520	110	681	480	380	100	24	27	9	30
Average	747	624	93	769	567	468	99	21	25	6*	26

* Denotes increase.

REMOVAL OF SUSPENDED MATTER. The removals of suspended matter for individual runs based both on actual and on computed analyses of the influent are given in table 81.

Table 81 indicates that results appear rather erratic and sometimes inconsistent when the efficiency is computed for a screen from

TABLE 82.

TESTS ON JENNINGS SCREEN AT MORGAN ST. AND WEAND SCREEN AT SULZBERGER & SONS.

Date 1913	Duration of Test	Crude Sewage			Moist Screenings			Dry Screenings Lb. per Mil. Gal.	Air Press Lb. per Sq. In.
		Rate Gal. per 24 Hr.	Gal. per Sq. Ft. Screen Exposed	Total. Gal. Screened	Total Lb.	Lb. per Mil. Gal.	Per Cent Moisture		
				JENNINGS SCREEN					
Oct. 23....	8:45 a.m. to 2:45 p.m.	1,120,000	2.11	279,500	1,726	6,170	83.0	1,050	46
24....	8:45 a.m. to 1:45 p.m.	1,138,000	2.14	237,000	1,144	4,820	80.4	945	46
Nov. 4....	9:40 a.m. to 1:45 p.m.	1,305,000	2.45	222,000	1,640	7,390	86.6	990	45
5....	9:00 a.m. to 2:15 p.m.	1,440,000	2.71	314,000	2,471	7,860	82.0	1,420	49
19....	9:05 a.m. to 1:45 p.m.	1,203,000	2.37	234,000	1,681	7,200	82.5	1,260	47
Average....	....	1,241,000	2.36	....	.....	6,740	82.9	1,150	47
				WEAND SCREEN					
Oct. 22....	11:00 a.m. to 3:00 p.m.	860,000	0.70	143,200	333	2,320	86.1	320	80
23....	1:15 p.m. to 2:15 p.m.	820,000	0.67	34,160	595	17,400	83.8	2,820	0
27....	2:06 p.m. to 3:36 p.m.	905,000	0.74	56,500	371	6,570	85.4	960	..
28....	10:30 a.m. to 3:30 p.m.	755,000	0.62	157,700	1,880	11,900	81.9	2,160	80
29....	8:30 a.m. to 3:30 p.m.	746,000	0.61	217,500	3,175	14,600	84.8	2,220	75
30....	8:45 a.m. to 3:45 p.m.	862,000	0.70	252,000	3,210	12,700	87.0	1,650	80
31....	8:30 a.m. to 3:30 p.m.	905,000	0.74	264,000	2,575	9,750	82.8	1,680	80
Average....	....	836,000	0.68	....	....	10,790	84.3	1,690	..

actual analyses of the influent and effluent. This is due largely to the difficulties of representative sampling, the short duration of the tests, and the fact that the coarse suspended matter removed by the screen is not adequately represented in the small portions taken for analysis. The per cent. removals based on computed analyses are much more consistent and probably represent more fairly the actual performance of the screens. On this basis the Jennings screen showed an average removal of about 33 per cent. or 127 p. p. m. while the Sulzberger screen apparently retained about one-fourth of the suspended matter, representing an average removal of 202 p. p. m. The Jennings screen receives a deal of coarse suspended matter such as pieces of corn, straw, etc.

Table 82 shows the removal of suspended solids both as moist and dry screenings in lb. per mil. gal. On this basis, the Jennings screen removed about 6740 lb. of material with 83 per cent. moisture, equivalent to 1150 lb. of dry matter per mil. gal. The Sulzberger screen results fluctuated more widely, varying from 2320 to 17,400 lb. of material, with an average moisture content of 84 per cent., or from 320 to 2820 lb. of dry material per mil. gal. The average, weighted according to the volume treated, was about 10,790 lb. of moist screenings or 1690 lb. of dry screenings per mil. gal.

SCREENINGS. The material retained by the Jennings screen had a dirty greenish brown color and contained a very high percentage of volatile matter. The material removed at the Sulzberger plant was similar to that at the testing station. The high moisture content found at the testing station was noted in these tests as well.

ANALYSES OF SCREENINGS.

Sewage from Stockyards and from Sulzberger Sons Co.

Screen	Per Cent Moisture	Dry Basis—Percentage			
		Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble
Jennings........	84.3	1.71	91	9	2.6
Sulzberger.......	85.1	1.31	93	7	5.8

CLEANING. The compressed air used to clean the Jennings screen was very effective, blowing the screenings completely away. The blast, however, gradually destroyed the screen cloth. The high pressures should be reduced, to avoid costly replacement of screen fabric as well as expense for power. Experiments along this line are under way.

Air was supplied for the Sulzberger screen in so small a main that the pressure available proved too low to produce any marked cleaning effect. However, the screen was thoroughly cleaned with a fire hose after each run. One point brought out in the operation of this screen was a clogging effect due to the congelation of grease in the meshes of the screen, stopping one test after a run of one hour. Careful attention to this detail is evidently required in handling straight packing-house wastes.

LOSS OF HEAD EXPERIMENTS ON MESH SCREENS.

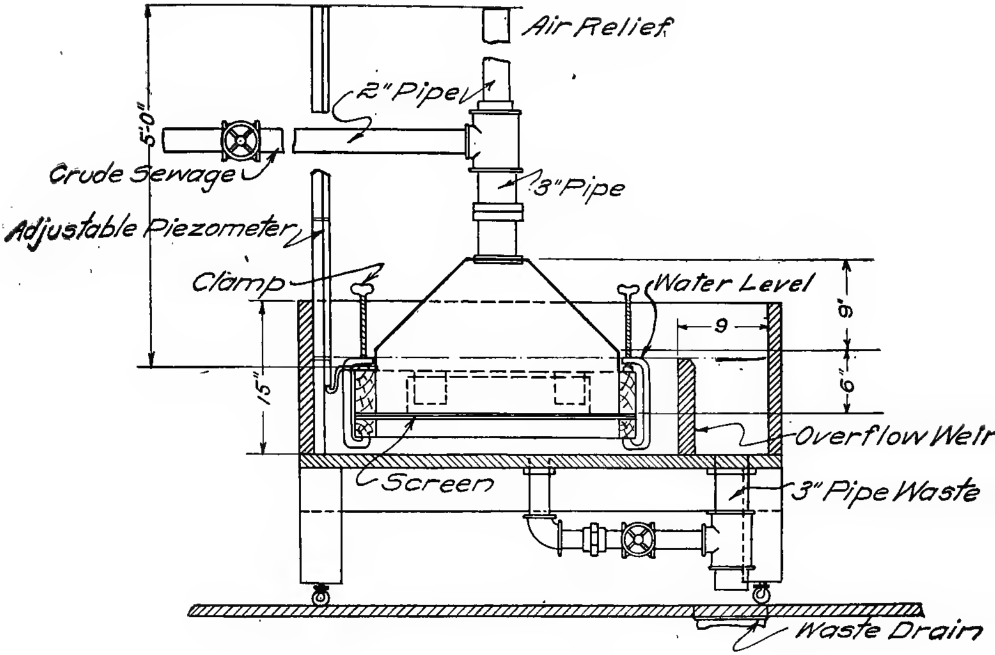
OBJECT. These experiments were conducted to determine the amount of sewage of the character received at the Stock Yards testing station which can be handled by screens of different mesh, the rate of clogging, and the relation, if any, between the amount of material retained on the screen, the rate of clogging, and the quantity of sewage treated.

APPARATUS. The apparatus (fig. 14) consisted of a square box of galvanized iron with pyramidal top and watertight joints. The screen to be tested was placed over the open bottom, being held in place between two wooden frames, one of which surrounded the outside of the box being attached thereto. The outer or lower frame was detachable, with a rubber gasket inserted between, the frames being held together by carriage makers' clamps. From the main orifice box, a two-inch pipe supplied sewage through the top, a flange union facilitating quick breaking of connections, being inserted. An air vent was also provided.

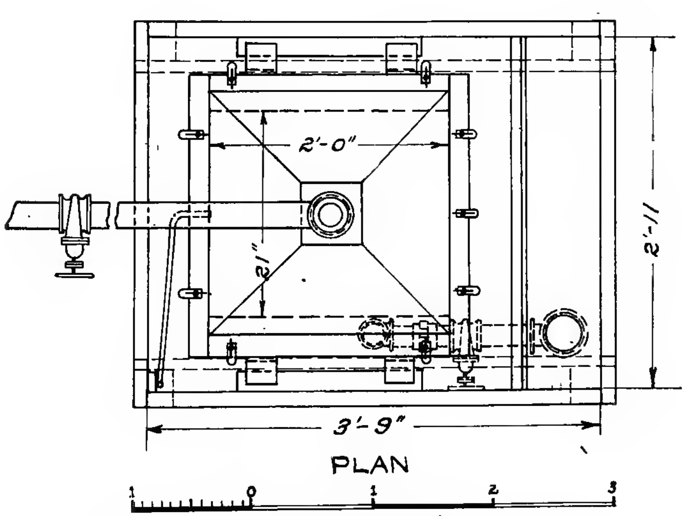
The screen box was set in a larger wooden box of tank construction with an overflow weir sufficiently high to keep the screen constantly submerged. The effluent discharged into the waste drain. The head on the screen was measured by an adjustable glass piezometer tube, with rubber tube connection to the side of the box, a constant level being maintained outside the screen by the overflow weir.

As originally designed, the screen box was exactly two feet square inside, but this was cut down to accommodate the screens already on hand, by inserting a wooden frame. The effective screen area was 3.5 sq. ft. The apparatus was designed for a maximum loss of head of 5 ft. but in actual tests 4.5 ft. was not exceeded.

METHOD OF CONDUCTING EXPERIMENTS. Screens of eight different sizes were employed, of 4, 6, 10, 16, 20, 24, 30 and 40 meshes to the linear inch, with mechanical properties indicated in table 83. Duplicate runs were made on each screen, except the No.



SECTIONAL ELEVATION



PLAN

Scale-Feet

Fig. 14. Apparatus for Screening Experiments.

4, on two and in some cases on three separate days. Piezometer readings were made every 15 sec. as soon as the screen began to clog.

TIME OF CLOGGING. The average results for screens of different mesh (fig. 15) show curves similar in form, indicating in general that when once the screen begins to clog, the loss of head increases with great rapidity, despite individual variations. Some difference is noted between the fine and coarse screens, after appreciable clogging appeared, the No. 6 screen requiring 7 min. to rise from practically zero to the final loss of 4.5 ft., whereas for the No. 40 screen the time in no case exceeded two minutes. The time required to produce clogging varied for different runs on the same mesh. With this sewage, however, constantly changing in strength, the wide variations in suspended matter content would produce considerable fluctuations in the time of clogging.

With the finer screens, the total time to reach the final loss of head was very short, not exceeding 6 min. for the No. 40 screen. With larger meshes, the average length of run increased but individual cases of very short runs occurred with screens as coarse as the No. 16, suggesting that the details of cleaning must be carefully

TABLE 83.

LOSS OF HEAD EXPERIMENTS.

Properties of Fine Screens.

Meshes per Lineal Inch Nominal	Diameter of Wire Inch	Net Opening Length of Side		Open Space Per Cent of Gross Area
		Inch	Millimeters	
4	0.048	0.198	5.04	65
6	0.034	0.137	3.48	64
10	0.026	0.072	1.83	54
16	0.019	0.042	1.07	42
20	0.016	0.034	0.86	46
24	0.0133	0.029	0.74	42
30	0.012	0.022	0.56	41
40	0.010	0.015	0.38	28

considered where fine screening is used, if undue clogging is to be prevented. Clogging with the No. 4 screen proceeded very slowly. Of the three runs, one reached the 4.5 ft. loss of head after 5 hrs. 30 min., the remaining runs, after intervals of 7 hrs. 30 min. and 6 hrs. respectively, having a loss not exceeding 0.01 or 0.02 ft. In all these tests the sewage passed a ⅝ in. bar screen before reaching the loss of head apparatus.

A few runs were made on the No. 30 and No. 40 screens at a

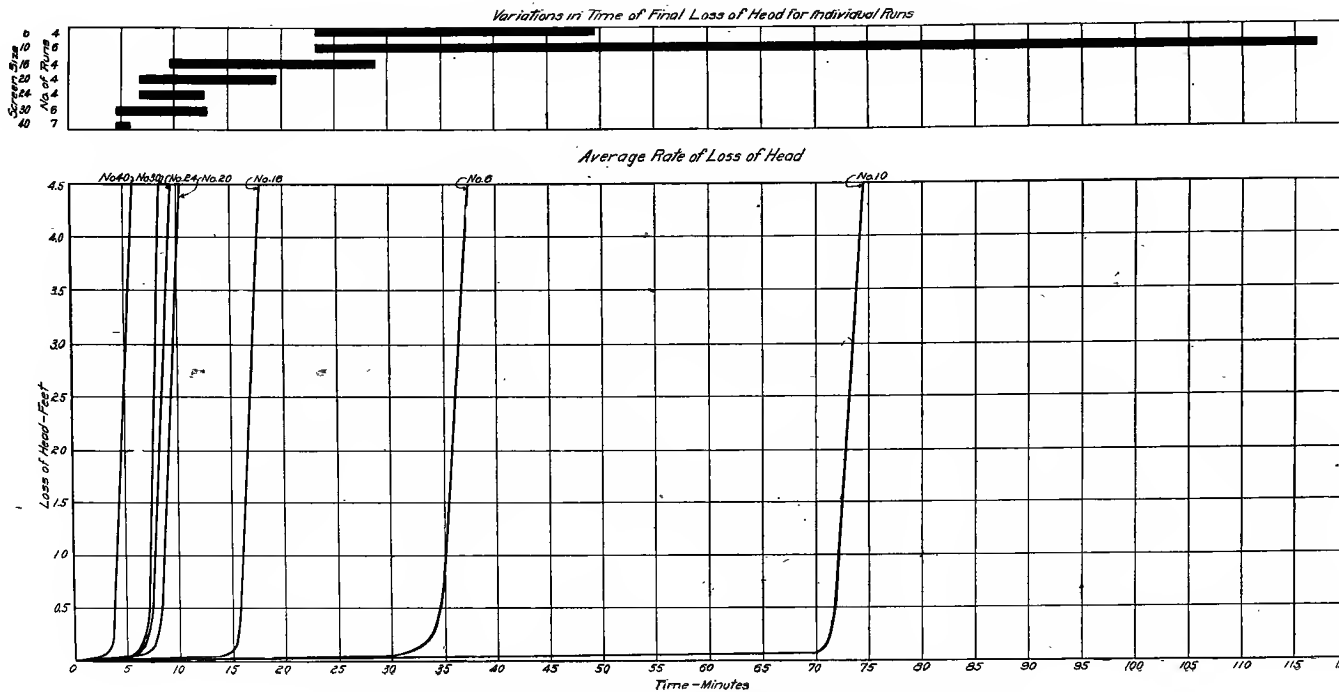


Fig. 15. Screening Experiments showing Time of Clogging.
Note. Screens were run at a rate of 14,800 gal. per sq. ft. per 24 hr.

TABLE 84.

LOSS OF HEAD EXPERIMENTS.

Reduction in Suspended Matter Through Fine Screens.

Date 1913	Size of Screen	No. of Runs Avgd.	Rate, Gal. Sq. Ft. Daily	Suspended Matter in Parts per Million						Per Cent Reduction		
				Influent			Effluent					
				Total	Volatile	Fixed	Total	Volatile	Fixed	Total	Volatile	Fixed
Aug. 8	6	2	14,800	620	510	110	610	440	170	2	14	54*
14	6	3	14,800	420	300	120	380	280	100	10	7	17
Sept. 2	10	1	14,800	660	530	130	450	400	50	32	25	62
2	10	1	14,800	460	400	60	330	300	30	28	25	50
3	10	2	14,800	660	360	300	640	380	260	3	6*	13
5	10	2	14,800	420	330	90	380	330	50	10	0	44
July 18	16	2	14,670	560	400	160	510	370	140	9	8	12
Aug. 15	16	1	14,800	750	460	290	620	530	90	17	15*	69
15	16	1	14,800	750	580	170	720	580	140	4	0	18
Aug. 7	20	2	14,750	770	550	220	670	510	160	13	7	27
12	20	2	14,800	680	430	250	500	330	170	26	22	32
July 24	24	3	14,700	500	460	40	460	440	20	8	4	50
Aug. 15	24	1	14,800	570	400	170	520	380	140	9	5	18
15	24	1	14,800	640	500	140	620	360	260	3	28	86*
Aug. 7	30	2	14,800	1200	1000	200	890	570	320	26	43	60*
12	30	3	14,800	700	470	230	520	330	190	26	30	17
21	30	1	14,800	390	240	150	390	230	160	0	4	7*
21	30	1	14,800	540	320	220	440	320	120	18	0	45
Sept. 2	30	1	6,840	470	390	80	300	280	20	36	23	75
3	30	2	6,840	520	240	280	590	330	260	13*	37*	7
July 11	40	2	14,680	720	570	150	600	430	170	17	25	13*
29	40	3	14,720	510	400	110	450	340	110	12	15	0
Aug. 8	40	2	14,800	730	620	110	680	580	100	7	6	9
22	40	1	6,840	490	370	120	390	250	140	20	32	17*
29	40	1	6,840	920	790	130	710	600	110	23	24	23
29	40	1	6,840	840	680	160	640	500	140	24	26	13

* Denotes increase.

lower rate, approximating 6840 gal. per sq. ft. daily. The duration of the runs increased somewhat, averaging 9 min. 27 sec. for 4 runs on the No. 40 screen, against 5 min. 16 sec. for 7 runs at the higher rate, and 46 min. 7 sec. for 3 runs on the No. 30 screen, against 8 min. 36 sec. for 6 runs at 14,800 gal. per sq. ft. daily. The average time for the No. 30 screen at the low rate was high, principally owing to an unusually long run on Sept. 22, extending over 76 min. 22 sec. With a low rate, the loss of head increased more gradually than at the high rate, extending over 4 or 5 min. at the low rate compared with 2 min. for the high.

REDUCTION IN SUSPENDED MATTER. The analyses of influent and effluent samples, with the percentage reduction of suspended matter (table 84), show considerable variations in the strength of the crude sewage, as well as in the per cent. reductions. As all the experiments were made between 9 A. M. and 4 P. M., when the sewage was strongest, the results are typical of the worst conditions.

The percentage reduction in suspended matter was very erratic, varying between wide limits for screens of the same size and following no clearly defined rate of increase for decreasing size of mesh. In fact a considerable decrease is noted in the average results in some cases. This apparent fluctuation in efficiency was probably due to the difficulty of collecting representative samples, and to the short duration of runs, as well as to actual variations in efficiency and sewage applied.

Since the larger particles of suspended matter are retained on the screen, thus removing one source of sampling errors, the effluent samples are presumably more typical of the actual composition of the liquid than are the influent. In table 85 are indicated the actual analyses of the effluent and computed analyses of the influent based on the weight of dry material retained by the screen and the quantity of sewage passed through. The percentage reductions are figured also on this basis. For comparison, the actual analyses of the influent and percentage reductions based thereon are shown. The calculated figures in general indicate a progressive increase in efficiency with decreasing size of mesh, the fluctuations in individual cases being much smaller. This probably represents more closely actual conditions, as the finer screens are undoubtedly more efficient in removing suspended matter. Owing to the difficulties of sampling, however, the relative amounts of material actually removed by the various screens are a better index of efficiency than are the percentage reductions of suspended matter. These latter figures indicate an average percentage removal of from about 13

TABLE 85.

LOSS OF HEAD EXPERIMENTS.

Reduction in Suspended Matter from Computed Analyses of Influent.

Date	Size of Screen	No. of Runs Avgd.	Rate, Gal. per sq. ft. per 24 hr.	Suspended Matter Parts per Million: Influent Actual	Suspended Matter Parts per Million: Influent Computed	Suspended Matter Parts per Million: Effluent	Per Cent Reduction: Actual Infl.	Per Cent Reduction: Computed Infl.
1913								
Aug. 6.....	6	2	14,800	620	680	610	2	10
14.....	6	3	14,800	420	452	380	10	16
	Average	5	14,800	500	543	472	6	13
Sept. 2.....	10	1	14,800	660	492	450	32	9
2.....	10	1	14,800	460	368	330	28	10
3.....	10	2	14,800	660	713	640	3	10
5.....	10	2	14,800	420	418	380	10	9
	Average	6	14,800	547	520	470	14	10
July 18.....	16	2	14,670	560	644	510	9	21
Aug. 15.....	16	1	14,800	750	740	620	17	16
15.....	16	1	14,800	750	807	720	4	11
	Average	4	14,740	655	709	590	10	17
Aug. 8.....	20	2	14,750	770	785	670	13	15
12.....	20	2	14,800	680	605	500	26	17
	Average	4	14,780	725	695	585	19	16
July 24.....	24	3	14,700	500	594	460	8	23
Aug. 15.....	24	1	14,800	570	621	520	9	16
15.....	24	1	14,800	640	765	620	3	19
	Average	5	14,740	542	634	504	7	21
Aug. 7.....	30	2	14,800	1200	1018	890	26	13
12.....	30	3	14,800	700	689	520	26	24
21.....	30	1	14,800	390	514	390	0	24
21.....	30	1	14,800	540	611	440	18	28
Sept. 2.....	30	1	6,840	470	404	300	36	26
3.....	30	2	6,840	520	679	590	13*	13
	Average	7	14,800	776	747	596	23	20
	Average	3	6,840	497	587	493	1	16
July 17.....	40	2	14,680	720	836	600	17	28
29.....	40	3	14,720	510	605	450	12	26
Aug. 8.....	40	2	14,800	730	914	680	7	26
22.....	40	1	6,840	490	521	390	20	25
29.....	40	1	6,840	920	968	710	23	27
29.....	40	1	6,840	840	864	640	24	26
	Average	7	14,730	633	759	559	12	26
	Average	3	6,840	750	784	580	24	27

*Denotes increase.

NOTE. Final loss of head equals 4.5 ft.

TABLE 86.

LOSS OF HEAD EXPERIMENTS.

Dry Screenings in Pounds per Million Gallons and per Square Foot Before Clogging.

Size of Screen Nom. Mesh	Rate, Gal. per Sq. Ft. per 24 Hr.	Individual Runs							Maximum	Minimum	Average
		DRY SCREENINGS IN POUNDS PER MILLION GALLONS									
4	14,800	139	124	140	....	....	....	....	140	124	134
6	14,800	715	450	545	805	....	....	....	805	450	654
10	14,800	353	313	687	535	330	307	....	687	313	421
16	14,800	1,386	847	1,010	725	....	....	....	1,386	725	992
20	14,800	915	1,010	1,100	650	....	....	....	1,100	650	919
24	14,800	1,350	1,055	847	1,205	....	....	....	1,350	842	1,113
30	6,840	865	758	705	....	....	....	....	865	705	776
30	14,800	1,050	1,085	1,060	1,910	1,030	1,420	....	1,910	1,030	1,259
40	14,800	2,410	1,530	1,225	1,260	1,390	1,760	2,140	2,410	1,225	1,674
40	6,840	1,055	1,095	2,145	1,863	....	....	....	2,145	1,055	1,290
		DRY SCREENINGS IN POUNDS PER SQUARE FOOT									
4	14,800	0.51	....	....	....	....	....	....	....	....	0.51
6	14,800	0.17	0.23	0.28	0.22	....	....	....	0.28	0.17	0.23
10	14,800	0.38	0.38	0.16	0.21	0.32	0.23	....	0.38	0.16	0.28
16	14,800	0.22	0.25	0.10	0.13	....	....	....	0.25	0.10	0.18
20	14,800	0.06	0.10	0.10	0.13	....	....	....	0.13	0.06	0.10
24	14,800	0.11	0.09	0.06	0.16	0.14	0.13	....	0.16	0.06	0.11
30	14,800	0.08	0.09	0.07	0.17	....	....	....	0.17	0.07	0.10
30	6,840	0.31	0.14	0.08	....	....	....	....	0.31	0.08	0.18
40	14,800	0.14	0.08	0.06	0.08	0.07	0.09	0.09	0.14	0.06	0.09
40	6,840	0.04	0.06	0.07	0.09	....	....	....	0.09	0.04	0.07

NOTE. Final loss of head 4.5 feet except for No. 4 screen on two runs.

per cent. for the No. 6 screen to 26 per cent. for the No. 40 screen at a rate of approximately 15,000 gal. per sq. ft. per day.

The analyses of the effluent probably give a slightly lower suspended matter content than the real content of the liquid passing the screen, owing to sedimentation in the wooden tank before the effluent passed over the waste weir and was sampled. This error in general appeared small, increasing, however, with the size of screen and length of run. The amount deposited during the runs with the No. 4 screen was considerable, one measurement showing an accumulation at the rate of 375 lb. per mil. gal., representing approximately 45 p. p. m. of suspended matter. The amount of material retained on this screen was, however, very small, consequently the amount of settling material passing through was proportionately large. Owing to the relatively great effect of this factor on the results of the No. 4 screen, the percentage reductions were omitted from tables 84 and 85. For the other screens, this factor is probably negligible.

SCREENINGS. Ordinarily the screenings were drained for a short time before weighing. The moisture content usually varied from 80 to 87 per cent., averaging approximately 84 per cent. The weight of screenings for individual runs per mil. gal. of sewage is given in table 86, as well as the weight per sq. ft. at final loss of head. Fig. 16 shows these results plotted graphically against the net length of mesh opening, indicating the variation in the amount retained per million gallons, especially for the screens of fine mesh. The removal depends both on the nature and amount of matter in suspension. The greater variation with the fine screens may also have been caused by the comparatively short duration of the runs, thus making the period of vigorous loss of head a greater portion of the total time. Presumably after clogging had become established, the amount of suspended matter screened out increased somewhat, as the mat already formed would act as a strainer. Hence, variations in the strength of sewage affect more markedly the amount of suspended matter removed by the fine screens. The finer the screens the greater the removal of suspended matter. The amount of screenings depends also on the relation of the net opening of screen to the gross area, varying almost directly with this percentage up to the No. 10 size and at a lower rate for coarser screens. Of two screens having the same percentage of net opening, Nos. 16 and 24, the latter removed more suspended matter, averaging 1113 lb. per mil. gal., compared with 992 lb. for No. 16 mesh.

In a few runs made on Nos. 30 and 40 mesh, the lower rate, 6840 gal. per sq. ft. daily, seemed to give a somewhat smaller accu-

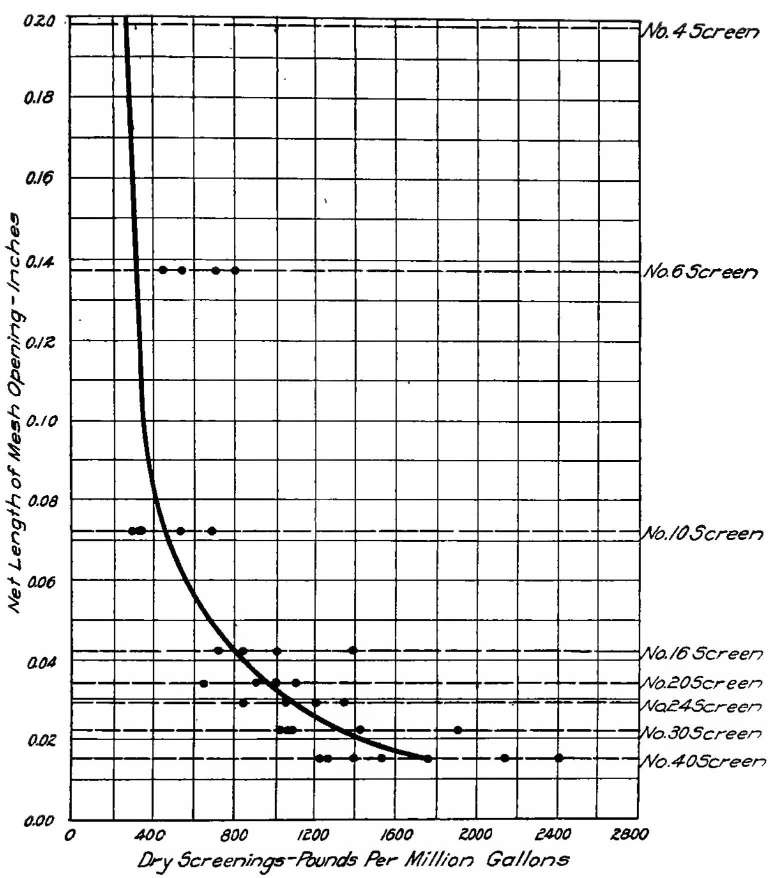


Fig. 16. Removal by Screens of Various Mesh.
Note. Dots represent Individual Runs.
All data secured with apparatus in Fig. 14.

mulation (table 86). The reasons for this are uncertain, although changes in character of the sewage may be largely responsible.

The amount of material removed per mil. gal. is much greater than for similar tests at the 39th Street testing station, even making allowance for the fact that most of the latter were made to a final loss of head of 0.4 ft. (table 87).

Table 87 shows that, except for the No. 4 screen, four to six times more suspended matter was screened from the Stockyards sewage than from the 39th Street.

TABLE 87.

SCREENING EXPERIMENTS.

Comparative Results Obtained with Mesh Screens on Crude Sewage at Stockyards and 39th Street.

Size of Screen Nom. Mesh	Stockyards Sewage			39th St. Sewage		
	No. of Tests	Gal. Per Sq. Ft. Daily	Dry Screen'gs Lb. Per Mil. Gal.	No. of Tests	Gals. Per Sq. Ft. Daily	Dry Screen'gs Lb. per Mil. Gal.
4	3	14,800	134	1	12,000	87
6	4	14,800	654	4	12,000	121
10	6	14,800	421	4	12,000	117
16*	4	14,800	992	..	......	...
20	4	14,800	919	4	6,150	210
24*	4	14,800	1113	..	......	...
30	6	14,800	1259	4	12,000	190
30	3	6,840	776	2	6,150	206
40	7	14,800	1674	4	6,150	295
40	4	6,840	1290	..	.....	...

* Not used in 39th St. tests.

Note. Stockyards tests carried to final loss of head of 4.5 ft., 39th St. experiments to 0.4 ft.

TABLE 88.

ANALYSES OF SCREENINGS.

Date	Size of Screen	Specific Gravity	Calculated to Dry Weight			Per Cent
			Nitrogen	Volatile	Fixed	Ether Soluble
1913						
July 10.....	24	....	2.72	..	..	6.62
18.....	16	....	2.96	..	..	6.56
29.....	40	0.99	3.28	90	10	7.42
Aug. 7.....	20	1.02	3.36	90	10	8.44
12.....	30	1.03	3.68	87	13	6.66
21.....	30	1.03	2.88	88	12	5.30

ANALYSES OF SCREENINGS. The material retained by the screens resembled that caught by the rotary screen. With the coarser screens the screenings formed a mat-like layer, which could be stripped with little difficulty, leaving the meshes comparatively clean. With the fine screens, on the other hand, some of the material was forced into the meshes, adhering so firmly that scrubbing and washing was necessary to clean the screen thoroughly. Typical analyses are given in table 88.

LOSS OF HEAD EXPERIMENTS WITH SLOTTED PLATES.

GENERAL. Beside the experiments on mesh screens, tests were made on slotted iron plates. These slots were cut square and were not bevelled on one edge as is done in the Riensch-Wurl screen. Three widths of slot were provided, the mechanical properties of

TABLE 89.

MECHANICAL PROPERTIES OF SLOTTED PLATES.

Designation	Dimensions of Slots, Inches			Area of One Slot Sq. In.	Gross Area Plate Sq. Ft.	Per Cent Net Opening to Gross Area
	Length	Width	Distance C. to C.			
Coarse......	1.00	0.0625	0.198	0.0625	3.5	28.4
Medium.....	0.50	0.032	0.125	0.0160	3.5	17.6
Fine........	0.50	0.025	0.083	0.0125	3.5	17.2

these plates being indicated in table 89. On the coarse plate the slots were staggered, in the others the slots were arranged diagonally in 42 rows, 1/6 in. apart.

The tests were run to a uniform loss of head of 1.5 ft., at a rate of approximately 11,100 gal. per sq. ft. per 24 hrs.

TABLE 90.

INTERVAL REQUIRED TO REACH LOSS OF HEAD OF 1.5 FEET

At Rate of 11,100 Gallons Per Sq. Ft. Daily.

Size of Slot	No. of Runs	Time for Final Loss of Head in Min. and Sec.		
		Average	Minimum	Maximum
Coarse........	7	28–45	12–32	43–18
Medium.......	8	9–08	5–00	12–04
Fine..........	8	7–14	4–05	13–19

TIME OF CLOGGING. The average, maximum, and minimum intervals required to reach the final loss of head (table 90) indicate that the loss of head proceeded somewhat more slowly, if more irregularly, than with the mesh screens after clogging. Runs of short duration on all three widths of slot indicate that the details of cleaning would require careful design to prevent undue loss of head with rates approaching those used with plates having substantially the same percentage of openings.

REDUCTION IN SUSPENDED MATTER. The results of individual runs on slotted plates and average results for mesh screens of the nearest size are shown in table 91. The mesh screens were tested at a rate of 14,800 gal. per sq. ft. per 24 hr. to a final loss of head of 4.5 ft., whereas the slot screens were tested at a rate of 11,100 gal. per sq. ft. per 24 hr. to 1.5 ft. loss of head.

TABLE 91.

SLOTTED PLATE SCREENS.

Percentage Reduction in Suspended Matter.

Coarse Slots 1.00x0.0625 In.			Medium Slots 0.50x0.032 In.			Fine. Slots 0.50x0.025 In.		
Susp. Mat. Parts Per Mil.		Percent Reduction	Susp. Mat. Parts Per Mil.		Percent Reduction	Susp. Mat. Parts Per Mil.		Percent Reduction
Infl.	Effl.		Infl.	Effl.		Infl.	Effl.	
420	356	15	370	298	19	394	312	21
528	424	20	370	270	27	390	316	19
364	336	8	478	366	23	459	316	31
393	360	8	364	288	21	652	404	38
397	372	6	403	324	20	170	144	15
477	376	21	344	268	22	316	240	24
512	432	16	353	308	13	364	292	20
...	...	..	535	444	17	409	348	15
Avg. 442	379	14	402	321	20	394	297	25
MESH SCREENS								
No. 10 (0.72 In.)			No. 20 (0.034 In.)			No. 30 (0.022 In.)		
Avg. 520	470	10	695	585	16	747	596	20

The efficiency decreases with increasing width of slot, the smallest slots being most efficient. The average reduction in suspended matter appears to be greater than with screens of nearly corresponding opening operated under somewhat different conditions, even though the accumulation of screenings in pounds per million gallons was greater with the screens. The sewage was somewhat weaker during the summer of 1914 when the plate experiments

were carried on, than in 1913, when the first series was run on the screens. Hence, the proportion of coarse suspended matter may have been relatively higher. Owing to the limited number and brief duration of runs, the results are not conclusive as to the comparative merits of slotted plates and mesh screens.

SCREENINGS. Ordinarily, after draining for a few minutes before weighing, the screenings contained from 80 to 90 per cent. of moisture, and resembled in every way the catch on the mesh screens. No analyses were made. The accumulation in lb. of dry material per mil. gal. for individual runs with average results for mesh screens of the nearest size (table 92) show slightly higher retentions for the mesh screens in the finer sizes. The average results given for the No. 10 mesh screen are undoubtedly too low because two runs were unusually long.

TABLE 92.

ACCUMULATION OF DRY SCREENINGS.

Pounds Per Million Gallons.

	Coarse (0.0625 In. Slot)	Medium (0.032 In. Slot)	Fine (0.025 In. Slot)
	535	600	680
	866	836	618
	234	935	1190
	271	635	2070
	208	655	215
	840	376	635
	666	635	599
	...	755	507
Avg.	517	678	814
Average for Screens of Nearest Corresponding Mesh			
	No. 10 (0.072 In.)	No. 20 (0.034 In.)	No. 30 (0.022 In.)
	421	919	1259

RESULTS. The results of these tests on slotted screens indicate that a considerable removal of suspended matter may be obtained with slots of the size used, which is probably somewhat lower than with screens of corresponding mesh.

ADDITIONAL SCREENING EXPERIMENTS.

GENERAL. Beside the loss of head experiments made in 1913 on fine screens up to 40 meshes per lin. in., a few tests were made in September and October, 1914, on screens of 60, 80 and 100 meshes to the lin. in., in a manner similar to the previous sets, but

at a rate of 2940 gal. per sq. ft. per 24 hr., the final loss of head being 1.5 ft. The lower rate was employed to extend the runs sufficiently to give reasonably accurate measurements.

RESULTS. The percentage removals based on computed analyses of the influent are shown below:

PERCENTAGE REMOVAL OF SUSPENDED MATTER BY FINE MESH SCREENS.

Meshes per Lin. Inch	No. of Tests	Susp. Mat. P. P. M.		Per Cent Reduction Susp. Mat.		
		Influent	Effluent	Average	Maximum	Minimum
100	6	345	244	29	45	18
80	5	300	200	33	35	24
60	6	328	251	23	34	14

In general, a higher efficiency is noted than with the screens of coarser mesh tested under somewhat different conditions. The difference is not great, however. The sewage used in these tests was considerably lower in suspended matter than during the first series.

The removal of dry material is indicated below in tabular form.

REMOVAL OF MATERIAL BY FINE SCREENS.

Meshes per Lin. Inch	No. of Tests	Screenings per Cent Moisture	Pounds per Million Gallons			
			Moist Screenings	Dry Screenings		
				Average	Maximum	Minimum
100	6	84.3	5400	840	1400	575
80	5	86.6	6370	830	1320	385
60	6	87.4	4960	640	1135	290

The average pounds of dry suspended matter removed for all fine meshes is less than for the previous tests of a No. 16 screen with a stronger run of sewage and slightly different conditions of operation. The percentage removals, however, were somewhat higher than reached by the No. 40 screen. The large difference in actual weight of dry material per million gallons is largely due to the difference in strength of the sewage, the suspended matter during the most recent tests averaging about one-half that for the first series.

CONCLUSIONS. With the very fine mesh screens employed somewhat larger removals of suspended matter appear possible than with the 30 or 40 mesh. The difference does not appear very great.

CHAPTER XII.

COMPARISON OF METHODS OF PRELIMINARY TREATMENT.

GENERAL. Three distinct methods of tank treatment were tried during these investigations,—(1) plain sedimentation in tanks of the Dortmund or upward flow type; (2) plain sedimentation in the Imhoff type of double deck tank with a separate chamber for the retention and digestion of sludge; (3) chemical precipitation in Dortmund tanks. Extensive investigations on the value of fine screening as a preliminary process were also made. The grit chamber, although a part in the scheme of preliminary treatment, is not here considered a separate process, as the removal of suspended matter ordinarily is slight, serving as an adjunct to the subsequent tank treatment.

REMOVAL OF SUSPENDED MATTER. As the reduction of suspended matter is the important point in all the processes just outlined, the percentage removals of suspended matter have been summarized in table 93. The figures for the devices involving plain sedimentation are based on monthly averages of daily or bi-daily samples, the figures for chemical precipitation for individual runs and the various screening experiments are for individual tests or runs. The reductions for both the plain sedimentation and chemical precipitation processes are given both for the day samples and for the entire 24 hours, although the precipitant was applied only for part of the day. The results of the screening tests are based on the computed influent analyses.

Table 93 indicates that about 9 to 25 per cent., based on computed analyses of the suspended matter, may on the average be removed by fine screening (30 or 40 mesh) with correspondingly smaller reductions for coarser sizes, depending on the hours when the screen is in operation. At individual plants, owing to greater concentration and freshness of wastes, greater efficiencies may be expected. Plain sedimentation in either the Dortmund or Emscher type of tank will remove from 50 to 70 per cent. of the suspended matter, according to the methods of operation. With chemical precipitation of the heavy day sewage and plain sedimentation for the weak night flow, a removal approximating 80 per cent. has been attained.

RETENTION OF SUSPENDED MATTER. Not only is the relative removal of suspended matter of moment in determining the efficiency of different settling devices, but the ability to retain the

TABLE 93.

PERCENTAGE REMOVAL OF SUSPENDED MATTER BY VARIOUS DEVICES

Device	Period of Flow Hours	Veloc. Ft. per Hour	Percent Removal Suspended Matter		REMARKS
			Day Samples	24-Hr. Samples	
Dortmund Tank	10.0	1.0	80	72	
	4.0	1.1	69	65	
	3.0	1.5	69	65	
	6.0	1.7	63	57	
	2.0	1.8	49	42	
	1.9	2.3	54	53	
	4.0	2.6	54	48	
	1.0	4.5	49	47	
Emscher Tank	4.0	1.9	52	45	
	3.0	2.5	50	47	
	2.0	3.8	51	48	
	1.5	5.0	53	50	
	1.9	9.2*	61	58	* Horizontal velocity.
	2.9	6.0*	72	69	* Horizontal velocity.
Chem. Precip.	3.0	3.5	76	72	5.5 gr. copperas; 10.3 gr. lime
	3.0	3.5	80	77	4.5 gr. copperas; 10.7 gr. lime
	3.0	3.5	84	79	3.5 gr. copperas; 9.9 gr. lime
	2.0	2.2	78	74	3.3 gr. copperas; 8.6 gr. lime
	2.0	2.2	67	68	3.5 gr. copperas; 5.1 gr. lime
	4.0	2.6	79	70	3.5 gr. copperas; 5.1 gr. lime
	4.0	2.6	82	74	2.4 gr. copperas; 5.2 gr. lime
	4.0	2.6	72	65	5.2 gr. copperas; 5.5 gr. lime
	6.0	1.7	77	..	4.9 gr. copperas; 6.0 gr. lime
	4.0	2.6	64	52	2.4 gr. alum 2.8 gr. lime
	4.0	2.6	73	66	3.0 gr. alum; 0.0 gr. lime
	4.0	2.6	82	76	1.9 gr. alum; 2.7 gr. lime
	4.0	2.6	80	76	3.2 gr. alum; 0.0 gr. lime
Rotary Screen—					
30 mesh				17	8:00 A. M. to 4:00 P. M.
30 mesh				12	7:30 A. M. to 10:30 P. M.
30 mesh				9	8:00 A. M. to 11:00 P. M.
Fine Screens—					
6 mesh				13	
10 mesh				10	
16 mesh				17	
20 mesh				16	
24 mesh				21	
30 mesh				20	
40 mesh				26	
Slotted Plates—					
Coarse				14	
Medium				20	
Fine				25	

NOTE.—Fine screen and slotted plate results are on special runs, not 24-hr., but short.

solid matter settled out is likewise important. In this respect the Emscher tank is desirable, since the design provides for automatically trapping the sludge to prevent it from being unloaded into the sewage again. During the ripening period and at times when the accumulation of sludge in the digestion chamber reached the level of the sludge ports, some unloading took place, bringing scum to the surface in considerable quantities. This, however, is not a defect in principle, but an element of design to be provided for.

Operation of tanks of the Dortmund type indicates that the sludge can in general be retained if the effluent channels are baffled and careful attention is paid to frequent cleaning. Frequency in cleaning is essential, especially during warm weather. However, the high temperature of the sewage combined with the larger organic content of the sludge all favor the rapid development of septic conditions with consequent tendency to unload.

After the chemical precipitation tests were thoroughly started, it was found easier to retain the sludge than when the same tank was operated as a plain settling device. The formation of any distinct scum was apparently prevented, except when alum was employed. However, septic conditions develop with the chemically precipitated sludge, necessitating careful attention to cleaning. The practically complete absence of scum in this process, however, makes the retention of settled material considerably easier, than for plain settling.

PERIOD AND VELOCITY OF FLOW. A comparatively short period of flow is sufficient for plain sedimentation in the Dortmund and Emscher tanks. With tanks of the upward flow or Dortmund type, vertical velocity appears to be more important than the detention period, for the highest removals of suspended matter were obtained at the lowest velocities irrespective of the detention period. However, with the same velocity, longer detention periods gave somewhat better results. Providing long periods of detention, in the Dortmund type of tank, is not economical, for with a vertical velocity of one or two feet an hour, which is most advantageous, and a period of say three hours, very shallow tanks result, which are practically straight flow tanks. An excessive number of units is also required. With higher velocities around 5 ft. per hr. and periods of 1.5 to 3 hrs., the removal is much lower. The difficulty of maintaining low vertical velocities applies also to the radial flow type of Emscher tank. With the straight flow Emscher tank, the indications are that a detention period of 2 to 3 hours is ample.

AMOUNT OF SLUDGE. The volume of sludge and scum ac-

cumulated per million gallons was greatest for the chemical precipitation treatment and lowest for the Dortmund tank C. The large amount of drier surface scum habitually present on Tank C explains in part the apparent inequality in rate of accumulation, as compared with the other tanks. Approximate average figures for various tanks are as follows:

Apparatus	Period of Flow	Cu. Yd. of Sludge and Scum per Mil. Gal.
Tank C	1.9 to 4 hours	6.0
Tank D	4 to 6 hours	9.5
Tank E	1.5 to 4 hours	8.0
Chemical Precipitation*	2 to 6 hours	13.0

* 15 hours daily, plain sedimentation rest of day.

The sludge from chemical precipitation considerably exceeds that resulting from plain sedimentation. The vigorous digestion going on in the Emscher tank eliminates a portion of the sludge deposited as gas, thus reducing the rate of accumulation. With the Dortmund tanks operating on a plain sedimentation basis, the rate of accumulation varies. The relative amounts of sludge and drier surface scum apparently influence the total volume markedly.

The low yardage shown for tank C may be due to difficulties in manipulation. The sludge remaining in a tank after incomplete withdrawal is usually much thinner than originally. Hence the amount withdrawn calculated from measurements made before and after cleaning may be too low. Ultimately the thin sludge compacts to its former condition. The net result is to show a lower rate of accumulation than was actually the case. Tank C was cleaned very frequently, tank E, least frequently. The true rate of accumulation, therefore, for tank C is probably higher than recorded.

QUALITY OF SLUDGE. For drying on sludge beds, the Emscher tank sludge proved superior. The entrained gases made the sludge light and porous, readily parting with a portion of its water, and drying comparatively quickly to a porous earthy mass, easily handled by spading. The chemical precipitation sludge, on the contrary, was very sticky, requiring considerably longer periods for drying, whereas the sludge from plain sedimentation in Dortmund tanks was intermediate between the two. All of the scums, although initially drier than the sludges, were much harder to reduce to a spadeable condition, and were usually very offensive The well digested Emscher sludge showed a considerable loss of volatile matter with a consequent reduction in calorific value. The fresh sludges

from the Dortmund tank, if artificially dried, would contain considerably more thermal units. The fresh chemical precipitation sludge with a large content of inert mineral matter is low in heating value.

SCUM FORMATION. Scum was consistently present on the Dortmund tanks at all times while operated on a plain sedimentation basis, accumulating so rapidly that its removal became a problem. Unless the formation can be prevented, it will prove troublesome. Careful attention to the details of baffling will be of value, but will not wholly prevent the scum from passing off in the effluent. Preliminary fine screening may remedy this difficulty, as tests to date indicate that it will afford some relief. The only difficulty from this cause in the operation of the Emscher tank appeared during the ripening period, and when the sludge chamber was excessively full of sludge. The scums in general appeared to consist largely of light suspended materials of a fibrous nature, such as straw, chaff, hair, etc.

In addition to the scum forming in the gas vent of the Emscher tank, a scum, somewhat different, consisting largely of grease has persisted on the surface of the settling chamber more or less regularly. The removal of the grease from the sewage appears to be the only cure.

The chemical precipitation tank has been consistently free from scum. Small clots of the floc, with the lighter suspended matter entangled therein, appeared in limited quantities, but no continuous mat of scum has been recorded, except with the use of alum in place of copperas, when a heavy scum soon formed.

ODOR. The question of odor may perhaps not appear so important in this problem as ordinarily, since the general aerial nuisance from the Stockyards and Packingtown suffices to completely overwhelm any slight local odors which might come from the plant. On general principles, however, it is desirable to avoid odors so far as practicable.

Of the different methods of tank treatment, the Emscher tank was on the whole the least open to criticism. The sludge, as discharged, had only a slight tarry odor, noticeable only a few inches away, although occasionally hydrogen sulphide was perceptible. At times, on top of the tank, a distinct odor was perceptible from the gas vent, particularly during the ripening period when the gas funnel was filled with scum, for then, when stirred, the scum had an offensive odor, distinctly containing hydrogen sulphide After ripening, during the summer of 1913, this tank was in violent ebullition

continuously, but nothing more than a trace of hydrogen sulphide could be found.

Comparatively little odor was noticed from the Dortmund tanks except when the surface scum was stirred up or when sludge was being discharged. In the latter case, in the vicinity of the tank an offensive putrid odor was frequently noticeable. The odor from the scums, especially when wet, was particularly offensive during removal.

When operated as a chemical precipitation tank, the sludge from Tank D frequently had a peculiarly sweet sickish or metallic odor, decidedly offensive and entirely distinct from the other sludges. At times this was strong in the immediate vicinity of the tank.

TABLE 94.

AVERAGE MONTHLY TEMPERATURES OF CRUDE SEWAGE IN CENTER AVE. SEWER, AND VARIOUS EFFLUENTS.

Date	Average Monthly Temperature in Degrees Fahrenheit								Remarks
	Air†	Crude Sewage	Grit Chamber Effluent	Tank C Effluent	Tank D Effluent	Tank E Effluent	Sprinkling Filter Effluent	Basin F Effluent	
1912									
Sept.*	59	85	84	..	82	82	..	..	*15 days
Oct.	59	80	80	..	77	78	..	..	....
Nov.	43	70	70	..	68	67	..	..	....
Dec.	33	66	68	..	67	65	..	..	....
1913									
Jan.	29	65	65	..	64	63	..	..	....
Feb.	25	62	62	..	60	60	..	..	....
Mar.	35	60	61	..	58	58	..	..	....
Apr.	49	67	68	..	66	62	..	..	....
May	58	75	75	..	73	73	..	..	....
June	71	84	84	..	83	83	..	..	....
July	75	87	87	86	86*	86	..	..	*19 days
Aug.	74	89	89	88	88	88	..	..	....
Sept.	65	86	86	84	84	84	57*	..	*7 days
Oct.	53	77	77	76	76	76	56	..	....
Nov.	47	73	73	72	..	71	51	50*	*4 days
Dec.	37	70	70	69	68	69	47*	49*	*18 days
Avg. 1913	52	75	75	79	73	73	53	49	....
1914									
Jan.	32	64	64	63	62	64	44	45	....
Feb.	20	63	63	60	59	62	44	44	....
Mar.	36	63	64	62	60	61*	47*	48*	*Part of
Apr.	48	69	69	67	67	68	55	55	month
May	62	74	74	73	72	73	64	65	....
June	70	84	84	83	83	83	71	71	....
July	75	93	93	91	92	91	78	78	....
Aug.	74	93	93	90	91	91	78	79	....

† U. S. Weather Bureau on Federal Building, Chicago.

The material removed by the rotary screen was entirely inodorous and inoffensive when fresh. After lying on the ground in thin layers for a few days, however, a very foul putrid odor developed in the under layers.

OPERATION. Most of the details of operation were discussed indirectly under other headings, particularly the formation of scum, disposal of sludge, and details of cleaning. However, chemical precipitation also involves constant attention to the application and control of the chemicals, as well as to the more complicated apparatus required

TEMPERATURE. Ice formed upon the tanks, only when the surface layers of scum froze, the initially high temperature of the sewage preventing freezing, particularly as the drop in temperature in passing through the tanks rarely exceeded two degrees Fah. (Table 94).

CONDITIONS OF FLOW. All results have been based on a uniform rate of flow through the tanks for the entire 24 hours. As a matter of fact the flow in the sewer fluctuates between wide limits at different times during the day. The bulk of sludge deposited in the tanks settles out during hours of heavy day flow, however, and if this is used as a basis for design, the rate of accumulation and necessary detention period should differ little from the results obtained at the uniform rate. Analyses of the tank influents and effluents show that in general less than 10 per cent. of the total suspended matter deposited during the entire 24 hours settles out during the nine night hours.

SETTLING EXPERIMENTS. To determine the settling characteristics of the sewage, tests were run under quiescent conditions in a manner similar to those first made at Cologne, Germany*, and identical with those made at the 39th St. pumping station.

The apparatus used in our experiments consisted of a cylindrical galvanized iron can 2 ft. in diameter and 9 ft. deep, fitted with taps and nipples projecting inside the can to the center so that the samples drawn were taken from points in a vertical line. Crude sewage was admitted rapidly at the bottom, keeping the contents thoroughly stirred during the filling. The run was assumed to start on the completion of filling. Samples were taken from each of the taps as soon as the can was filled, and a composite sample made to represent the crude sewage. The can was filled to a depth of 8 ft. 6 in. Samples were withdrawn for analysis 18 in. below the surface at the time in-

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*Mittheilungen aus der Königlichen Prüfungsanstalt für Wasserversorgung und Abwässerbeseitigung. Berlin, Heft. 4, pp. 40-45.

tervals indicated in table 95. The Cologne experiments were made in a vessel 15¾ in. square and 8 ft. 2½ in. deep, the contents being stirred with a paddle prior to the beginning of the run. The samples were collected from a tap 6 ft. 6¾ in. above the bottom, or 19¾ in. below the surface.

The results of our tests (table 95) indicate marked reductions in total and volatile suspended matter. To make clearer the relation between sedimentation time and percentage removal of suspended matter, the removals have been plotted (Fig 17), the results of the 39th St. experiments being added for comparison. As the available data on the Cologne experiments give only the removal of volatile matter, a second plot (Fig. 17), has been inserted, showing the percentage removals of volatile matter, including both the 39th St. and the Cologne experiments. To show the effect of varying amounts of suspended matter in the crude sewage, the results have been averaged and plotted by groups according to the initial suspended matter.

With the weak 39th St. sewage, a substantial reduction takes place, both of total and volatile suspended matter, up to the 4th or 5th hour. With the very heavy Stockyards sewage, the reduction after two hours was slight, while the comparatively strong Cologne sewage deposited most of its settleable volatile matter within the first two hours, although the increase in reduction for the next two or three hours was somewhat greater than for the Stockyards sewage.

The quiescent experiments indicate that a removal of from 54 to 93 per cent. of the total material in suspension may be attained by 2 hr. quiescent settling, while at the end of 12 hr., the removal varied from 55 to 97 per cent., according to the original content of suspended matter. An average removal of 76 per cent. was attained at the end of 2 hr., while the removal at the end of 12 hr. averaged 79 per cent., which probably represents approximately the percentage of settling solids. The removal at the end of two hours is appreciably better than in the tanks with the same theoretical detention period, but the former results are raised by the inclusion of a number of tests from sewage much higher in suspended matter than the average throughout the day, and the percentage removals were correspondingly greater. With identically the same sewage, a slightly greater removal might occur under quiescent conditions.

Samples taken at the end of 12 hr., at depths of 7 ft. 0 in., 7 ft. 9 in. and 8 ft. 3 in., showed a considerably smaller decrease in suspended matter over the results obtained at depths of 18 in. and in some cases an actual increase was recorded. This simply indicates

TABLE 95.

EXPERIMENTS ON SETTLING UNDER QUIESCENT CONDITIONS.

Date 1913	Hour A.M.	Susp. Mat. p.p.m.	Per Cent Removal 18 in. Below Surface After														Per Cent Removal after 12 Hours at Depth of		
			Minutes								Hours								
			5	10	15	20	25	30	40	50	1	2	3	4	6	12	7′–0″	7′–9″	8′–3″
PER CENT REDUCTION IN TOTAL SUSPENDED MATTER																			
June 23	8	1930	68	81	86	87	88	88	85	90	91	93	95	96	98	97	90	88	92
27	8	1630	43	63	71	76	77	80	76	80	80	84	..	92	90	77	61	66	61*
25	8	1620	44	65	77	76	82	80	83	84	82	85	87	89	92	90	82	87	85
July 14	11	1070	14	49	61	67	69	70	70	73	70	73	73	80	79	77	..	..	..
9	10	950	31	59	65	76	70	80	76	78	83	85	88	87	85	85	50	43	33
2	9	880	15	32	44	48	48	48	53	48	44	67	69	73	76	77	34	31	30
8	10	850	28	60	68	68	73	72	79	79	79	78	72	78	85	94	59	51	13
16	11	840	36	36	57	62	63	64	66	70	69	66	67	69	66	55	43	36	43
June 30	9	760	41	58	67	69	72	71	74	74	67	73	73	80	74	82	84	71	45
July 11	10	560	9	25	43	52	43	48	52	48	54	54	57	54	57	57	4	14*	21*
PER CENT REDUCTION IN VOLATILE SUSPENDED MATTER																			
June 27	8	1140	40	58	65	71	71	75	74	75	78	81	..	89	88	75	60	60	59
25	8	840	52	71	82	82	85	84	88	90	88	91	91	93	94	94	84	92	90
July 2	9	730	17	30	43	44	44	40	49	45	55	62	66	70	75	75	34	38	30
June 23	8	650	43	61	69	71	71	69	72	74	76	79	82	86	87	85	75	75	79
July 9	10	620	29	50	61	72	60	71	66	68	76	79	83	81	82	80	50	45	34
8	10	560	18	48	59	54	63	59	70	70	70	68	63	72	80	95	40	29	3*
16	11	560	25	20	46	54	54	55	55	60	57	55	57	66	64	73	48	30	27
11	10	540	2*	54	54	..	61	59	69	69	59	67	70	72	72	70	..	..	..
June 30	9	460	42	54	61	62	76	63	63	63	52	61	63	72	67	72	78	63	37
July 11	10	420	7	24	41	53	45	53	50	45	50	53	55	48	52	52	7	16*	16*

*Denotes increase.

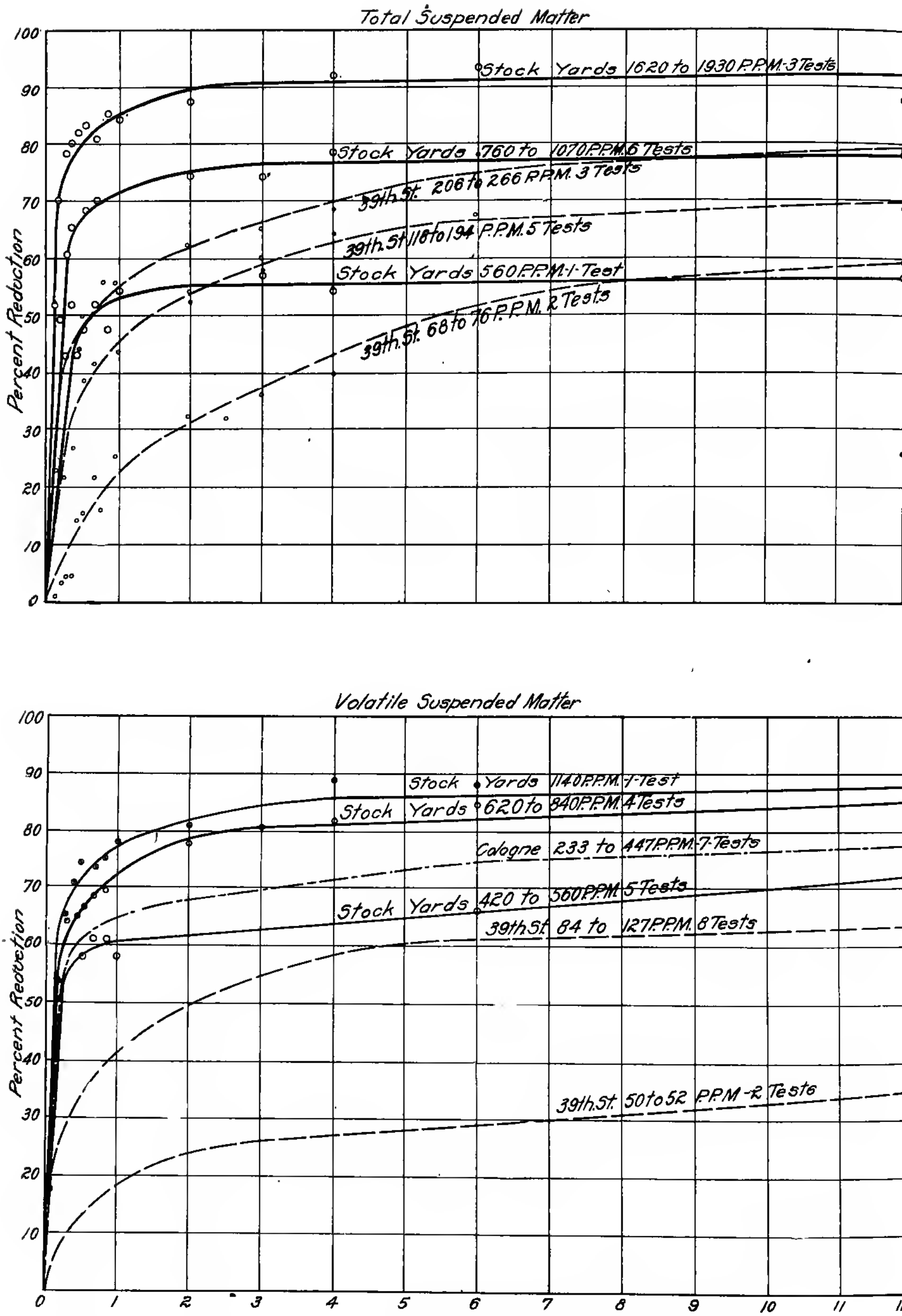

Fig. 17. Removal of Suspended Matter by Quiescent Settling.

Note. Upper diagram is based on total suspended matter. Lower diagram is based on volatile suspended matter.

that practically all the suspended matter had dropped to the bottom of the can.

The conclusion to be drawn from these experiments is that a comparatively short sedimentation period is sufficient for the removal of most of the suspended matter in this sewage under quiescent conditions. In tanks of the upward flow type where the upward velocity is opposed to the descending settling matter, these results would be modified somewhat. With horizontal velocities, however, fairly rapid settlement may be expected. A removal of from 55 to 97 per cent. of the total suspended matter is attained at the end of 12 hr., representing the proportion of suspended solids which may be assumed as capable of subsidence. The average removal at the end of 12 hr., 79 per cent., is probably somewhat high for the average sewage of the entire 24 hr.

CHAPTER XIII.

SPRINKLING FILTER.

GENERAL. The construction of the filter has been described in Chapter IV. A $\frac{7}{8}$ in. Taylor nozzle, throwing a circular spray, was used, on account of the limited head available on the square bed, and in all calculations relating to rate of dosing, the effective area has been taken as that of a circle tangent to the sides of the filter, namely 171 sq. ft. or 0.00393 acre.

RATE. Table 96 shows the schedule of operation. Up to April 1, 1914, a net yield of about $\frac{3}{4}$ mil. gal. per acre daily was secured, a rest of one day in seven being provided. During the winter this rate was somewhat exceeded, owing to the necessity for continuous operation to prevent freezing. On Apr. 1, 1914, the rate was increased to give a net yield of approximately one mil. gal. per acre daily, and on Aug. 1, 1914, the rate was still further increased.

TABLE 96.

SPRINKLING FILTER.

Monthly Summary of Operation.

Date	Av. Hr. Operated Daily	Gross Rate Mil. Gal. per Acre per 24 Hr.	Yield, Mil. Gal. per Acre per 24 Hr.	Remarks
1913				
Sept. 22 to 30...	23.2	0.844	0.816	Started Sept. 22
October	20.8	0.844	0.733	....
November......	19.9	0.844	0.700	....
Dec. 1 to 18	20.9	0.902	0.782	Shut down Dec. 18 for repairs.
1914				
Jan. 3 to 31.....	22.2	0.941	0.900	Started Jan. 3.
February.......	21.8	0.839	0.758	....
Mar. 1 to 9; 20 to 31...........	21.6	0.810	0.730	Shut down Mar. 9 to 20.
April...........	20.5	1.190	1.017	....
May...........	19.7	1.186	0.978	....
June...........	19.9	1.135	0.941	....
July	18.8	1.238	1.012	....
Aug.	19.8	1.438	1.188	....

ANALYSES. Monthly averages of the filter effluent are shown in table 97. The comparative results with the other devices, tested by the biologic oxygen consumed method, are given in table 113.

REDUCTION IN SUSPENDED MATTER. Table 98 shows the average monthly reduction in suspended matter for the

TABLE 97.
ANALYSES OF EFFLUENT FROM SPRINKLING FILTER.

Date	Parts per Million								Sampling Period
	Nitrogen as				Oxygen Consumed	Suspended Matter			
	Total Organic	Free Ammonia	Nitrites	Nitrates		Total	Volatile	Fixed	
1913	DAY SEWAGE—SUNDAYS OMITTED.								
Sept. 22 to 30	22	30	1.0	5.4	57	98	66	32	10:00 a.m. to 12:00 Mid.
Oct.	18	23	2.2	21.0	63	321	146	175	9:30 a.m. to 11:30 p.m.
Nov.	24	25	1.2	19.2	58	144	99	45	"
Dec. 1 to 18	17	25	1.2	23.7	51	135	103	32	"
1914									
Jan. 3 to 31	24	29	0.6	8.4	..	109	71	38	"
Feb.	18	27	0.5	10.8	..	122	88	34	"
Mar. 1 to 9 & 20 to 31	14	19	0.9	17.1	..	117	80	37	"
Apr.	19	19	1.3	17.5	..	208	148	60	10:00 a.m. to 12:00 Mid.
May	17	13	3.4	22.2	..	140	...	...	"
June	9	14	5.8	20.0	..	99	...	...	"
July	8	9	6.2	15.9	..	81	...	...	"
Aug.	8	11	3.2	15.8	..	73	...	...	"
1914	NIGHT SEWAGE								
Jan. 3 to 31	10	18	.3	3.2	..	63	44	19	12:30 a.m. to 8.30 a.m.
Feb.	7	16	.3	8.3	..	69	52	17	"
Mar. 1 to 9 & 20 to 31	9	11	0.1	14.9	..	120	77	43	"
Apr.	12	12	1.3	12.0	..	158	111	47	1:00 p.m. to 9:00 a.m.
May	8	6	2.0	19.0	..	131	...	...	"
June	5	6	3.7	17.5	..	72	...	...	"
July	5	6	3.8	13.2	..	74	...	...	"
Aug.	7	6	1.5	14.1	..	64	...	...	"
1914	DAY AND NIGHT (24 Hour) SEWAGE—SUNDAYS OMITTED.								
Jan. 3 to 31	19	25	0.4	6.0	..	90	59	31	
Feb.	14	23	0.4	9.5	..	104	75	29	
Mar. 1 to 9 & 20 to 31	12	17	0.8	14.7	..	121	79	42	
Apr.	16	16	1.2	14.4	..	183	132	51	
May	9	10	2.9	20.9	..	127	...	...	
June	9	11	4.9	18.2	..	86	...	...	
July	7	9	5.3	14.7	..	71	...	...	
Aug.	8	9	2.6	15.2	..	70	...	...	

TABLE 98.

SPRINKLING FILTER.

Removal of Suspended Matter.

Date	Suspended Matter in Parts per Million						Per Cent Reduction			Remarks
	Influent††			Effluent						
	Tot.	Vol.	Fixed	Tot.	Vol.	Fixed	Tot.	Vol.	Fixed	
1913	DAY SAMPLES—SUNDAYS OMITTED.									
Sept. 22 to 30	258	210	48	98	66	32	64	69	33	....
October	248	184	64	321	146	175	29*	21	174*	....
November .	262	205	57	144	99	45	45	52	21	....
Dec. 1 to 18	276	231	45	135	103	32	51	55	29	....
1914										
Jan. 3 to 31.	228	180	48	109	71	38	52	61	21	....
February ..	193	154	39	122	88	34	37	43	13	....
Mar. 1 to 9; 20 to 31..	173	147	26	117	80	37	32	46	42*	....
April.......	137	111	26	208	148	60	52*	33*	131*	Filter unloading
May.......	156	...	...	140	...	...	10	...	...	....
June.......	112	...	...	99	...	...	12	...	...	....
July	107	...	...	81	...	...	24	...	...	....
Aug.......	83	...	...	73	...	...	12	...	...	....
1913	NIGHT SAMPLES—SUNDAYS INCLUDED, IN 1913.									
Sept. 22 to 30	88	74	14	233	128	105	163*	73*	650*	....
October. ...	84	63	21	318	136	182	279*	116*	767*	....
November .	98	69	29	137	88	49	40*	28*	69*	....
Dec. 1 to 18.	95	66	29	105	72	33	10*	9*	14*	....
1914										
Jan. 3 to 31.	86	63	23	63	44	19	27	30	17	....
February...	52	39	13	69	52	17	33*	33*	31*	....
Mar. 1 to 9; 20 to 31..	89	70	19	120	77	43	35*	10*	126*	....
April.......	51	38	13	158	111	47	210*	192*	261 *	Filter unloading
May.......	58†	...	...	115†	...	...	98*	...	...	†Ten days only
June.......	57	...	...	72	...	...	20*	...	...	
July	53	...	...	74	...	...	40*	...	...	....
Aug.......	43	...	...	64	...	...	59*	...	...	....
1913	DAY AND NIGHT (24 Hours) SEWAGE—SUNDAYS OMITTED.									
Sept. 22 to 30	197	163	34	148	89	59	25	45	42	....
October. ...	196	144	45	319	142	177	63*	1	293*	....
November .	204	158	46	147	99	48	28	37	4*	....
Dec. 1 to 18.	210	171	39	124	91	33	41	47	15	....
1914										
Jan. 3 to 31.	164	127	37	90	59	31	45	54	16	....
February ..	141	111	30	104	75	29	26	32	3	....
Mar. 1 to 9; 20 to 31..	141	116	25	121	79	42	14	4*	68*	....
April.......	104	83	21	183	132	51	76*	59*	143*	Filter unloading
May.......	125†	...	...	123†	...	...	2	...	...	†10 days only
June.......	92	...	...	86	...	...	7	...	...	
July	87	...	...	78	...	...	11	...	...	....
Aug.......	68	...	...	70	...	...	3*	...	...	....

* Denotes increase.

†† Emscher tank effluent.

day, night and 24-hr. samples. The effluent has been consistently high in suspended matter, especially in October, 1913, the percentage reduction on the 24-hr. samples ranging from an increase of 76 per cent. to a decrease of 45 per cent. The increase in October, 1913, was doubtless due to the washing out of the residual dust adhering to the filtering medium, as the increase is entirely in the fixed matter. During the unloading period in April, 1914, the filter also was discharging more suspended matter than it received.

In the filter effluent was contained considerable suspended matter of a different character, however, from that in the influent, being fine, granular, and settling in the sample bottles with comparative rapidity. Mineralization of the suspended matter applied to the filter occurred to a considerable extent, as evidenced by the markedly higher proportion of fixed matter in the effluent and the lower percentage reduction in this constituent than in the volatile suspended matter. So far, the filter has stored less than 20 per cent. of the applied suspended material based on the chemical analyses of influent and effluent. Marked unloading occurred in April, 1914, a large increase in suspended matter over that applied being noted.

NITRIFICATION. A high degree of nitrification was quickly established, the nitrates in the effluent rising to 17.3 p. p. m. on Oct. 2, 1913, 10 days after the filter was placed in operation. Table 97 shows the monthly averages for nitrates in effluent. Ordinarily the Emscher tank effluent contains from 1½ to 4 p. p. m. of nitrates. The filter effluent has averaged about 17 p. p. m. on the day samples; after the first few days of operation. With the large increase in nitrates, a corresponding reduction in organic nitrogen, ranging from 60 to 77 per cent. occurred. A high reduction in oxygen consumed likewise is noted (Tables 38 and 97)

PUTRESCIBILITY. Samples for putrescibility were taken four times daily, at 3 A. M., 9 A. M., 3 P. M., and 9 P. M., being incubated for ten days at 20 deg. C., with the addition of methylene blue in 150 c.c., equivalent to 0.4 c. c. of a 0.05 per cent. aqueous solution. Twenty days was originally adopted as the incubation period, but it was found that samples not decolorized at the end of 10 days might, for all practical purposes, be considered stable The average results by months are shown in Table 99. Relative stability figures are shown in Table 100. These are computed from the Phelps tables, except that samples holding out for 10 days have been given a relative stability of 100.

The 3 A. M. and 9 A. M. samples represent the weak night sewage, while the 3 P. M. and 9 P. M. samples represent the strong day sewage.

TABLE 99.

SPRINKLING FILTER.

Results of Putrescibility Tests on Filter Effluent.

Date	Number of Samples					Per Cent Putrescible					
						10-Day Basis					4-Day Total
	3 A.M.	9 A.M.	3 P.M.	9 P.M.	Total	3 A.M.	9 A.M.	3 P.M.	9 P.M.	Total	
1913 Sept. 22 to 30...	1	2	2	2	7	0	0	50	100	43	29
October..	25	24	26	24	99	68	46	81	54	63	47
Nov.....	21	24	23	24	92	62	16	43	63	46	39
Dec. 1 to 18.....	11	13	16	13	53	45	54	50	69	55	43
1914 Jan. 3 to 31.....	22	24	23	23	92	95	92	96	91	93	88
Feb......	15	18	17	15	65	67	39	88	80	60	45
Mar. 1 to 9; 20 to 31	11	15	11	12	49	36	20	36	33	31	20
April.....	24	24	25	23	96	79	46	64	65	64	51
May	24	23	23	22	92	4	17	13	27	15	8
June	25	22	24	25	96	8	18	13	12	12	6
July.....	22	23	24	24	93	5	13	25	4	12	3
Aug.....	25	22	26	25	98	48	36	42	4	33	21

On the whole, there is little choice between day and night results in percentage of putrescible samples and relative stability. To date, about 35 per cent. of the 9 A. M. samples have been putrescible on the 10 day incubation basis, while for the other three sampling periods, the proportion of putrescible samples in each case has averaged close to 50 per cent. The better showing of the 9 A. M. samples is probably due to collection from the very end of the weak night flow when the filter had the longest opportunity to recover from the heavy day load, the effect of which apparently extends into the night, no appreciable improvement being noted at 3 A. M. Considering all samples collected in the course of the day, the percentage of putrescible samples thus far has averaged slightly under 50, with a relative stability averaging nearly 75. To correspond with the putrescibility tests, made at 39th St. to date, based on a 4 day incubation period, a column is inserted, giving the percentage of samples putrescible after 4 days. Under this less rigid test, the percentage of putrescible samples is considerably smaller, the decrease for individual months varying from 5 to 16 per cent.

Tests for biologic oxygen consumed (see chap. XV) show relative stability results in the later months even better than the

methylene blue test would indicate, practical stability having been attained.

DISSOLVED OXYGEN. Samples for the determination of dissolved oxygen were taken simultaneously with the putrescibility samples. The results, summarized by months in table 101, show that, practically at all times, the filter effluent contained a considerable amount of dissolved oxygen.

TABLE 100.

SPRINKLING FILTER.

Relative Stability of Filter Effluent.
Monthly Averages.

Date	Relative Stability Number					Remarks
	3 A.M.	9 A.M.	3 P.M.	9 P.M.	Average	
1913						
October	55	77	56	68	64	....
November	52	88	79	56	70	....
Dec. 1 to 18	62	82	80	71	74	....
1914						
Jan. 3 to 31	25	40	36	31	33	....
Feb. 1 to 8; 16 to 28	82	83	63	56	71	....
Mar. 1 to 9; 20 to 31	76	88	83	83	82	....
April	51	76	65	60	63	Unloading.
May	99	86	92	88	92	....
June	96	92	96	94	94	....
July	98	97	92	98	96	....
Aug.	70	85	80	95	83	....

NOTE: Samples holding out 10 days assumed to have relative stability of 100.

TABLE 101.

SPRINKLING FILTER.

Dissolved Oxygen in Filter Effluent.

Date	Dissolved Oxygen—Parts per Mil.					Per Cent Sat.
	3 A.M.	9 A.M.	3 P.M.	9 P.M.	Average.	
1913						
Sept. 22 to 30	7.6	9.4	8.0	7.7	8.2	78
October	5.1	8.2	7.5	4.1	6.2	55
November	5.1	8.2	7.5	4.1	6.2	55
Dec. 1 to 18	5.8	7.9	7.5	5.0	6.4	54
1914						
Jan. 3 to 31	3.0	3.7	4.2	3.5	3.6	29
February	6.4	4.8	4.8	2.8	4.8	39
Mar. 1 to 9; 20 to 31	5.5	5.4	4.0	3.4	4.6	40
April	3.7	3.9	3.3	2.8	3.4	32
May	4.4	3.2	3.7	2.4	3.4	35
June	5.6	5.4	4.9	4.5	5.1	56
July	5.6	5.2	4.9	5.4	5.2	63
Aug.	5.4	5.0	4.6	4.5	4.9	59

NOZZLE CLOGGING. The nozzle was protected by a screen made of common wire window screening, with 12 meshes to the lineal inch, placed in the orifice box Being operated with the orifice wide open, the tendency for clogging was minimized. Under these circumstances, the nozzle required comparatively little attention. Such clogging as occurred was caused largely by small balls of grease, probably formed as the sewage cooled in its flow to the filter as well as by detached pieces of fungous growths from the supply pipe. During the spring the loss of capacity of the pipe, due to growths, made cleaning necessary to maintain the spray at the outer edges of the filter. Occasionally, long thin particles of solid material such as bits of straw, etc., passed the screen and resulted in clogging.

BIOLOGICAL LIFE. Numbers of small white moth flies appeared soon after the filter started, hovering about the edges of the spray, but not leaving the immediate vicinity of the filter. With the approach of cold weather, they disappeared, except for a few warm days during the late fall, and reappeared in the spring They were not present to any marked extent during the summer of 1914. During the unloading period in April, very fine white worms became numerous in the filter effluent, large red worms being also found in the secondary basin sludge.

Shortly after the filter started, a brown, bacterial slime began to form on the surface stones, soon covering the whole surface of the filter, and persisted through the cold weather. At intervals, patches of the growth became detached from the stones, but these were promptly renewed.

ODOR. A distinct odor was perceptible in the immediate vicinity of the filter, resembling the odor from decayed vegetables. The scum and sludge removed from the secondary settling basin had the same odor. In a large installation, the open filters might produce an odor of sufficient intensity to require thorough precautions to avoid nuisance in the immediate vicinity.

TEMPERATURE AND ICE FORMATION. The filter ran throughout the winter, although a heavy ring of ice formed around the edges of the spray. Otherwise the surface was always open, except during protracted shut-downs, when a thin coating of ice sometimes formed. The high temperature of the sewage will undoubtedly prevent any trouble with ice on open filters.

APPEARANCE OF EFFLUENT. The effluent was almost uniformly free from turbidity. The suspended matter unloaded was coarse, granular, and quick settling.

SURFACE CLOGGING. No surface clogging of any consequence was noted. Before the unloading period in April, the sewage was slow to disappear at a few spots, but thereafter this condition entirely disappeared. Raking of the surface stones also helped.

EFFECT OF DEPTH AND SIZE OF STONE. The effect of variations in depth and size of stone was not studied. With a total depth of six feet, good results were obtained with the $1\frac{1}{4}$ to 2-in. stone. Presumably, greater depths would give an effluent of somewhat better quality.

Although no clogging of note has occurred thus far, it is possible that somewhat larger stone would facilitate the unloading of the large quantities of solid matter stored in the filter at times. The question of grease retention also is important, although up to date no difficulty has occurred. If larger stone is used, some increase in depth might be warranted.

GROWTHS IN PIPES. A black slimy fungous growth accumulated quickly in the supply pipe, sometimes attaining a thickness of $\frac{1}{8}$ in. seriously impairing the capacity of the pipe and making frequent cleanings necessary to maintain sufficient head on the filter nozzle. This suggests the value of ready accessibility in the distribution of sewage and tank effluents. The formation of a slimy scum was also noticed in the open wooden troughs supplying the tanks.

SECONDARY SETTLING BASIN.

REMOVAL OF SUSPENDED MATTER. Table 102 shows the percentage of suspended matter removed by the secondary settling basin, while uniformly operated with a detention period of from 1.0 to 1.5 hours, with a vertical velocity varying from 2.4 ft. per hr. to 3.5 ft. per hr. The removal of suspended matter was smaller than is desirable or attainable, considering the nature of the material in suspension. A lower velocity and longer detention period are apparently desirable.

Scum, especially during the warmer months, has frequently appeared. A tank of the Emscher type would retain the settling material and obviate most if not all of the scum.

PUTRESCIBILITY AND DISSOLVED OXYGEN. Samples for putrescibility (table 103) and dissolved oxygen determinations were taken 4 times daily, corresponding to the filter samples with allowance for the detention period in the basin. Relative stability figures are shown in table 103a.

The results of the dissolved oxygen tests (table 104) are practically the same as for the filter, a slight diminution in oxygen occurring through the tank.

TABLE 102.

SPRINKLING FILTER.

Removal of Suspended Matter by Secondary Settling Basin.

Date 1913–14	Suspended Matter—Parts per Mil. Influent Total	Influent Vol.	Influent Fixed	Effluent Total	Effluent Vol.	Effluent Fixed	Per Cent Reduction Total	Per Cent Reduction Vol.	Per Cent Reduction Fixed	Period of Flow Hr.	Upward Vel. Ft. per Hr.
DAY SEWAGE.											
Dec. 4–18	137	110	27	90	73	17	34	34	37	1.0	2.4
Jan. 3–31.	109	71	38	63	45	18	41	37	53	1.0	2.4
Feb.	122	88	34	112	77	35	8	12	3*	1.0	2.4
Mar. 1–9; 20–31..	120	82	38	53	41	12	56	50	68	1.0	2.4
April.....	208	148	60	99	74	25	52	50	58	1.0	3.5
May.....	126†	...	..	72†	..	..	43†	..	..	1.0	3.5
June.....	99	...	..	108	..	..	9*	..	..	1.0	3.5
July 1–22	90	...	..	76	..	..	16	..	..	1.0	3.5
" 22–31	65	...	..	60	..	..	8	..	..	1.5	2.4
Aug.....	73	...	..	33	..	..	55	..	..	1.3	2.7
NIGHT SEWAGE.											
Dec. 4–18	94	65	29	76	51	25	19	22	14	1.0	2.4
Jan. 3–31	63	44	19	41	29	12	35	34	37	1.0	2.4
Feb......	69	52	17	49	38	11	29	27	35	1.0	2.4
Mar. 1–9; 20–31..	120	77	43	121	75	46	1*	3	7*	1.0	2.4
April.....	158	111	74	86	61	25	46	45	64	1.0	3.5
May	109†	...	..	63†	..	..	42	..	..	1.0	3.5
June.....	72	...	..	60	..	..	17	..	..	1.0	3.5
July 1–22	75	...	..	59	..	..	21	..	..	1.0	3.5
July 22–31	72	...	..	33	..	..	54	..	..	1.5	2.4
Aug.....	64	...	..	32	..	..	50	..	..	1.3	2.7
DAY AND NIGHT SEWAGE (24 Hour).											
Dec. 4–18	125	95	30	84	62	22	32	35	27	1.0	2.4
Jan. 3–31	90	59	31	53	37	16	41	37	48	1.0	2.4
Feb......	104	75	29	90	62	28	14	17	4	1.0	2.4
Mar. 1–9; 20–31..	126	82	44	83	56	27	34	32	39	1.0	2.4
April.....	183	132	51	85	62	23	54	53	55	1.0	3.5
May.....	115†	...	..	65†	..	..	44†	..	..	1.0	3.3
June.....	86	...	..	92	..	..	7*	..	..	1.0	3.5
July 1–22	84	...	..	70	..	..	17	..	..	1.0	3.5
July 22-31	67	...	..	50	..	..	25	..	..	1.5	2.4
Aug.....	70	...	..	33	..	..	53	..	..	1.3	2.7

* Denotes increase.

† Part of month only.

SLUDGE. Table 105 gives the rate of sludge accumulation, varying considerably between individual measurements. Little scum appeared during cold weather, unless the flow was shut off for some time. With the approach of warm weather, scum formation became excessive, comparatively little sludge being retained in the bottom of the tank.

TABLE 103a.

SPRINKLING FILTER.

Relative Stability of Secondary Settling Basin Effluent.
Monthly Averages.

Date	Relative Stability Number					Remarks
	4 A. M.	10 A. M.	4 P. M.	10 P. M.	Average	
1913						
Nov.	100	100	100	100	100	
Dec.	74	78	85	69	76	
1914						
Jan.	36	42	30	34	35	
Feb.	78	79	63	47	67	
Mar.	65	87	84	78	79	
Apr.	62	89	77	59	69	
May	96	93	92	91	93	
June	100	97	93	91	95	
July	100	98	94	97	98	
Aug.	89	80	80	94	86	

NOTE.—Samples holding out 10 days are assumed to have relative stability of 100.

The sludge was uniformly of a dark brown color, of smooth consistency, with an odor resembling that of decayed vegetables. Typical analyses (table 106) show a comparatively large content of nitrogen, low fats, and a decreased percentage of volatile matter compared with fresh sludges. During the spring, the sludge removed from the tank contained numerous fine white worms.

TABLE 103

SPRINKLING FILTER.

Showing Results of Putrescibility Tests on Secondary Settling Basin Effluent.

Date	Number of Samples					Per Cent Putrescible					
	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Total	4 A.M.	10 P.M.	4 P.M.	10 P.M.	Total	Total (4 days)
1913											
Nov.26-30	4	4	4	4	16	0	0	0	0	0	0
Dec. 1-18	10	11	12	13	46	50	36	42	69	55	36
1914											
Jan. 3-31.	21	23	23	23	90	86	87	100	91	91	88
Feb......	16	17	16	15	64	38	35	69	93	58	52
Mar. 1-9; 20-31..	10	12	12	10	44	50	17	25	50	34	27
Apr......	24	22	24	23	93	71	18	46	65	51	43
May.....	21	18	20	21	80	10	17	20	14	15	10
June.....	24	21	24	24	93	0	10	21	25	15	3
July.....	23	22	23	24	92	0	5	9	4	4	2
Aug.....	25	20	26	25	96	28	40	27	8	25	17

TABLE 104.

SPRINKLING FILTER.

Dissolved Oxygen in Secondary Settling Basin Effluent.

Date	Dissolved Oxygen—Parts per Mil.					Per Cent Saturation	Remarks
	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Average		
1913							
Nov. 26 to 30 ..	8.1	8.4	8.1	8.6	8.3	73	....
Dec. 1 to 18	5.2	6.2	6.4	5.5	5.8	56	....
1914							
Jan. 3 to 31.....	2.7	3.3	4.1	3.5	3.4	28	....
February.......	6.6	4.4	3.8	3.3	4.5	37	....
Mar. 1 to 9; 20 to 31.........	3.5	4.3	1.9	3.5	3.4	29	....
April..........	2.7	4.2	2.9	2.4	3.0	28	....
May...........	4.6	2.9	2.6	2.6	3.2	36	....
June...........	5.2	4.5	4.6	4.1	4.6	51	....
July...........	5.0	4.5	4.6	4.9	5.0	61	....
Aug...........	4.6	4.6	4.4	4.3	4.5	54	....

TABLE 105.

SPRINKLING FILTER.

Showing Sludge and Scum Accumulation in Secondary Settling Basin.

Date 1914	Cubic Yards per Million Gallons									Flow Period Hrs.	Upward Velocity Ft. per Hr.	Remarks
	Since Last Measurement			Since Last Cleaning			Since Start					
	Sludge	Scum	Sludge and Scum	Sludge	Scum	Sludge and Scum	Sludge	Scum	Sludge and Scum			
Jan. 3........	...	...	...	...	...	...	...	...	...	...	...	Started
14........	0.5	0	0.5	0.5	0	0.5	0.5	0	0.5	1.0	2.4	....
19........	3.2	0	3.2	1.3	0	1.3	1.3	0	1.3	1.0	2.4	Cleaned
24........	4.2	0	4.2	4.2	0	4.2	2.0	0	2.0	1.0	2.4	....
28........	6.4	0	6.4	5.2	0	5.2	2.6	0	2.6	1.0	2.4	Cleaned
Feb. 6........	2.8	0	2.8	2.8	0	2.8	2.7	0	2.7	1.0	2.4	....
20........	5.5	0	5.5	4.3	0	4.3	3.3	0	3.3	1.0	2.4	Cleaned
28........	7.7	0	7.7	7.7	0	7.7	3.9	0	3.9	1.0	2.4	"
Mar. 19........	Measurement Lost											"
27........	2.7	0	2.7	2.7	0	2.7	3.7	0	3.7	1.0	...	....
Apr. 4........	5.0	0	5.0	4.0	0	4.0	3.9	0	3.9	1.0	3.5	....
10........	3.3	0	3.3	3.8	0	3.8	3.8	0	3.8	1.0	3.5	Cleaned
16........	6.4	0	6.4	6.4	0	6.4	4.0	0	4.0	1.0	3.5	....
30........	6.8	0	6.8	6.6	0	6.6	4.4	0	4.4	1.0	3.5	Cleaned
May 13........	3.1	0	3.1	3.1	0	3.1	4.3	0	4.3	1.0	3.5	"
26........	1.5	0	1.5	1.5	0	1.5	4.0	0	4.0	1.0	3.5	....
June 1........	0.6	3.1	2.5	1.0	2.4	3.4	3.8	0.1	3.9	1.0	3.5	Cleaned

TABLE 106.

SPRINKLING FILTER.

Showing Analyses of Sludge from Secondary Settling Basin.

Date 1913	Specific Gravity	Per Cent Moisture	Dry Weight—Percentage			
			Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble
1913						
Dec. 10	1.00	94.5	4.54	64	36	4.36
20	1.01	94.1	4.64	63	37	9.56
1914						
Mar. 27	1.02	95.5	3.76	67	33	4.48
Apr. 10	1.02	95.9	3.60	60	40	4.66
30	1.04	90.7	3.28	54	46	5.12

CHAPTER XIV.

FAT TREATMENT.

GENERAL. The fat content of the Center Ave. sewage and of the various tank sludges has been commented on previously. However, the large amount of fat normally present warranted special studies to determine the feasibility of fat removal by various methods and the influence of the fat on the treatment devices tried.

FAT CONTENT OF CRUDE SEWAGE. Fat analyses were not made as a routine procedure. The occasional determinations, summarized in table 15, were made on acidified samples, and therefore represent practically the entire fat content. Compared with the normal fat content of the 39th St. sewage, about 25 parts per million, and that of other domestic sewages, the fat in the day sewage, especially during the heaviest hours, is very high, although much lower in the night flow. Some seasonal variation undoubtedly occurs. The care in operating the skimming basins in the packing houses, as well as the kill, has an influence.

The fat appears in a scum on the surface of the grit chamber in cold weather, and on Bubbly Creek at all times. The scum forms largely by chilling, when the hot sewage comes in contact with the cooler air or river water.

Animal fat is essentially a mixture of stearine, palmitine and olein. The first two are solid at ordinary temperatures, having melting points of about 160 deg. and 150 deg. Fah., respectively. Olein is a liquid with a melting point of 23 deg. Fah. The melting point of a so-called fat or grease depends upon the relative proportions in the mixture of these three constituents. In September, 1913, the ether extract from the grit chamber scum had a melting point of about 79 deg. Fah. Since the temperature of the sewage during the warm months is above 79 deg. (Fig. 10), the tendency to congeal and rise as scum is largely lost. With cold weather, the accumulation of scum increases (table 20). The scum accumulating on the river continues during the summer, however, probably because of the chilling effect of the colder river water, seldom over 70 deg. Fah. The amount of fat recoverable in this way has led several packers to maintain skimming plants at the Ashland Ave. and Center Ave. outlets.

REMOVAL OF FAT BY VARIOUS DEVICES. Although scum is removed in large quantities from the surface of the grit chamber

TABLE 107.

FAT REMOVAL IN VARIOUS SETTLING TANKS WITH DAY SEWAGE—8 A. M. TO 10 P. M.

Date 1914	Ether Soluble Parts per Million				Per Cent Reduction			Fat Retention Lb. per Mil. Gal.		
	Grit Chamber	Emscher Tank	Dortmund Tank	Chemical Precip.	Emscher Tank	Dortmund Tank	Chemical Precipitation	Emscher Tank	Dortmund Tank	Chemical Precip.
Mar. 20 to 21	145	135	86	58	7	41	60	84	493	726
23 to 24	208	104	92	45	50	56	78	868	968	1360
25 to 26	178	75	79	49	58	56	72	860	826	1075
Apr. 20 to 25	129	45	59	69	65	54	47	701	585	500
27 to May 2	165	50	58	28	70	65	83	960	894	1145
May 4 to 9	142	75	83	47	47	42	67	670	493	793
11 to 16	145	55	108	33	62	26	69	751	310	935
18 to 23	186	97	103	91	48	45	51	743	693	793
Average	157	71	83	53	55	47	66	718	618	866

during cold weather, the amount of fat actually skimmed is only about 11 per cent. of the total fat in the sewage, as indicated by a series of tests on the day sewage covering one week in March, 1914. During the warmer months of the year, when little or no scum forms, a smaller recovery occurs.

The amount of fat removed from the day sewage (grit chamber effluent) by the various tanks is shown on table 107. The Emscher and Dortmund tanks removed approximately 50 per cent., which is equivalent to between 600 and 700 lbs. per mil. gal. Some change, in rates and velocities of flow were made during the period covered by these tests. With chemical precipitation treatment, the removal averaged 66 per cent., corresponding to a retention of about 900 lbs. per mil. gal. This may be due to the more complete precipitation of suspended solids and to the formation of insoluble lime soaps which are dragged down by the precipitant.

The results (table 108) for the Emscher tank and the sprinkling filter show that on an average about 50 per cent. of the grease leaving the grit chamber was retained by the tank while nearly 20 per cent. was caught in the filter, or approximately 225 lbs. per mil. gal. The chilling of the sewage by spraying probably causes the removal. As yet, there is doubt whether this grease is permanently retained in the interstices of the filter or whether it is unloaded wholly or

TABLE 108.

REMOVAL OF ETHER SOLUBLE MATTER IN SPRINKLING FILTER.

Day Sewage 8 A. M. to 10 P. M.

Date 1914	Ether Soluble Parts per Million			Per Cent Reduction			Pounds Retained Per Mil. Gal.		
	Grit Chamber	Emscher Tank	Sprinkling Filter	Emscher Tank	Sprinkling Filter	Total	Emscher Tank	Sprinkling Filter	Total
Mar. 20 to 21	145	135	29	7	73	80	84	885	969
23 to 24	208	104	24	50	38	88	868	668	1536
25 to 26	178	75	24	58	29	87	860	425	1285
Apr. 20 to 25	129	45	46	65	1*	64	701	8*	693
27 to May 2	165	50	46	70	2	72	960	33	993
May 4 to 9	142	75	45	47	21	68	670	250	920
11 to 16	145	55	32	62	16	78	751	192	943
18 to 23	186	97	86	48	6	54	743	92	835
June 15 to 16	161	74	46	54	17	71	726	250	976
24 to 25	150	70	28	53	28	81	667	350	1017
July 3 to 4	119	85	26	19	59	78	284	492	776
Average....	156	72	45	54	17	71	700	225	925

* Denotes increase.

in part. If retained, a progressive diminution in capacity may end in complete stoppage of the voids. No evidence of such clogging has as yet appeared. A sample of the slime scraped from the stones just below the surface of the bed showed an ether soluble content of 7.6 per cent. Tests lasting one week in March, 1914, showed the removal of residual fat by the secondary settling basin to be comparatively insignificant.

FAT IN SLUDGES. The fat removed from the sewage in the tanks should appear either in the sludge or scum. Routine analyses of sludges and scums were shown in tables of sludge and scum analyses in previous chapters. In general from 5 to 10 per cent. of the dry residue in the bottom sludge is ether soluble material, whereas the scums have averaged as high as 20 per cent., and the thin greasy scum, frequently appearing on the surface of the settling compartment of the Emscher tank, has contained as high as 50 per cent.

The routine sludge and scum analyses were all made by simple ether extraction without first acidifying the sample, and do not include the fats combined as soaps. A few random analyses, following, indicate that the total fat obtained after acidification may considerably exceed the amount usually determined.

COMPARISON OF ETHER SOLUBLE MATERIAL IN ACIDIFIED AND NON-ACIDIFIED SAMPLES.

Tank	Material	Ether Soluble Percentage of Dry Weight		Remarks
		Not Acidified	Acidified	
C	Scum	11.4	23.3	Chemical Precipitation
D	Sludge	7.4	10.0	....
C	Sludge	10.0	23.6	....
Grit Chamber	Scum	62.3	69.0	....
E	Scum	12.6	29.8	From gas vent

RECOVERY OF GREASE. Various experimentors have tried to recover the grease contained in sewage, but as a rule without success, largely because the cost of recovery is high, compared with the value of the products recovered. Ordinarily, the attempts have been confined to the sludge produced by sedimentation processes. The high content of water is apparently the chief obstacle to success, as drying by mechanical means or by heat is usually required.

The most notable instance of grease recovery probably is at Bradford, Eng., where large quantities of wool washing wastes are discharged. The sewage averages about 440 p. p. m. of fat. The

sludge is treated with sulphuric acid, heated to 212 deg. Fah. and pressed. The grease passes off with the hot press liquor and is subsequently separated in tanks and further treated with chemicals. In 1907 a slight profit was reported, but as certain salaries, interest and sinking fund charges were not included, this profit may be apparent rather than real. At Cassel, Germany, the sludge was pressed and the sludge cake dried and disintegrated with steam. The grease was separated by extraction with benzine and recovered by steam which was afterwards condensed and the grease separated. Notwithstanding the sale of fertilizer and grease, the process proved uneconomical. Attempts to treat wet sludge at Frankfort, Germany, with benzine proved too costly to be considered, although the dried sludge residue contained from 15 to 20 per cent. of grease.

At Oldham, Eng., it is proposed to treat the sludge with a small amount of acid and superheated steam in retorts. The grease will subsequently be recovered by condensation.

Experiments recently made in Boston, Mass., have indicated that treatment of the raw sewage by sulphur dioxide gas, produced by the burning of pyrites, facilitates the separation of fats to a marked extent. The cost of acidification in this manner is claimed to be slight as compared with the use of sulphuric acid. By drying the sludge and extracting the fat with some solvent, Mr. G. W. Miles claims that a profit can be realized from the sale of grease and fertilizer. The process has not as yet passed the experimental state, however, and has not been tried on a working scale.

The general conclusion elsewhere is that past attempts to recover grease on domestic sewages have not been profitable and that on industrial wastes a profit is seldom shown. However, a way may eventually be found to reduce the cost of sludge disposal by recovery of grease and fertilizer material, rather than as a commercial undertaking for profit.

ACID EXPERIMENTS.

GENERAL. The "cracking" or acidification of sewage to remove fat is used in many industrial plants, particularly on wool washing wastes. To learn whether acidification could increase the yield of fat from the Center Ave. sewage, tests were made in barrels and on a larger scale. In two preliminary tests, made in barrels each holding about 40 gal. of sewage, sulphuric acid was added to distinct acidification, the liquid being settled for 3 hr. under quiescent conditions. In the first experiment, the suspended matter was reduced from 684 to 26 p. p. m. and the fat from 250 to 52, a reduction of 79 per cent. In the second experiment, the suspended matter was

decreased from 596 to 20 p. p. m. and the fat from 288 to 69 p. p. m., a reduction of 76 per cent. The supernatent liquid, at the end of the sedimentation period, was, in both cases remarkably clear.

TANK TREATMENT. Large scale tests were made in Tank C. Commercial acid (66 deg. Bé. or 93.5 per cent.), diluted sufficiently to facilitate control by a small glass orifice with constant head overflow, was applied to the sewage in the influent trough a few feet before entering the tank between 8 A. M. and 11 P. M. The first results directly after the start on Aug. 11, 1914, were discarded, as acid was not added in sufficient amount to neutralize the alkalinity of the sewage. The results given are subsequent to Aug. 24. So far as possible, an amount of acid was added to acidify the tank effluent, but this result was not always attained. The average rate of application was about 3,200 lb. of 100 per cent. acid per mil. gal., equivalent to about 22.4 gr. per gal. To neutralize the average alkalinity of the day sewage, 300 p. p. m., calculated as $CaCO_3$, theoretically requires about 2,500 lb. per mil. gal. of acid. The rate of application was below this figure at times, and the alkalinity exceeded the average at other times.

The tank was operated on a 3-hr. period of sedimentation, acid being applied on an average for 14 hr. daily.

TABLE 109.

ACID TREATMENT OF DAY SEWAGE AT CENTER AVE.
AVERAGE RESULTS IN SUMMER, 1914.

Determination	No. of Days	Parts per Million		Per Cent Reduction
		Grit Chamber Effluent	Tank Effluent	
Nitrogen as				
Org. N	18	61	41	33
Free Amm.	18	20	20	0
Nitrites	18	0.37	0.09	76
Nitrates	18	2.38	2.04	14
Chlorine	20	1000	1000	0
Oxygen Consumed	20	169	119	30
Suspended Matter				
Total	16	385	112	71
Volatile	16	306	96	69
Fixed	16	79	16	80
Alkalinity	20	260	-46	..
Fats	14	135	42	69

RESULTS OBTAINED. The average results available to date (table 109) indicate that acid treatment materially affects only the fat, by producing a higher recovery of fat, namely an average of 69 per cent. as compared with 47 per cent. for the period on which figures are available on a plain sedimentation basis (table 107). The latter average was secured under somewhat different conditions of operation. The fat removal is lower than that observed in the barrel experiments. A considerably higher reduction in fats was also noted as a result of chemical precipitation treatment. This very likely was due to the formation of insoluble lime soaps with the excess lime which afterwards settled out. From the standpoint of oxygen demand, an apparent improvement was noted in both tank and barrel experiments, as follows:

Device	No. of Days Tested	Biologic Oxygen Consumption P. P. M.	Per Cent Reduction B. O. C.	Settling Period Hr.
Grit Chamber	7	915	..	...
Acid Tank (C)	7	294	68	3.0
Chem. Pre. Tank (D)	6	505	33	4.0
Emscher Tank (E)	7	552	40	3.0

In obtaining the oxygen demand, the acid effluent was neutralized with sodium bicarbonate and inoculated with a few drops of grit chamber effluent. The results apparently are better than those for the other tanks (table 111). Possibly this is due to the more complete removal of colloidal matter in the acid treatment. Probably the better results are apparent rather than real and are due to the sterilization of the bacteria originally present and the retardation of subsequent decomposition, under conditions of test. The organic matter present when discharged into a stream and thoroughly inoculated, would undoubtedly produce results of a liquid more unstable.

When acid was added, scum formed comparatively slowly, the surface of the tank remaining free from one to two weeks after cleaning. Eventually scum appeared, however. The average rate of accumulation in cu. yd. per mil. gal. was 5.1 for the sludge and 2.0 for the scum. The sludge flowing from the tank was then a dirty yellowish gray color. The scum also was thin and foul in odor. Typical analyses are given on the following page.

Compared with sludges derived from other treatments, the fat content is apparently very high. But as the routine analyses were made without acidifying the sample, the difference is less than ap-

ACID TREATMENT OF SEWAGE.

Analyses of Sludge and Scum.

Date 1914	Specific Gravity	Per Cent Moisture	Dry Weight—Percentage				Remarks
			Nitrogen	Volatile Matter	Fixed Matter	Ether Soluble	
Aug. 18........	1.02	94.0	2.74	76	24	22.3	Sludge
24........	1.02	95.8	3.12	88	12	25.3	Sludge
24........	1.01	88.2	3.64	81	19	26.3	Scum

pears, and reference to the results on page 190 indicates that the difference in many cases is very slight.

COST. With an average alkalinity of 300 p. p. m., as Ca CO_3, about 2,500 lb. of 100 per cent. H_2SO_4 per mil. gal. would be required to exactly neutralize the sewage. On a practical scale, an excess of the theoretical dose would be required to insure acidity at all times, probably 3,000 lbs. per mil. gal. Rogers and Aubert (treatise on Industrial Chemistry) give the cost of manufacture of tower acid (about 78 per cent. strength) by burning pyrites as \$6.50 per ton, equivalent to about \$8.35 per ton of 100 per cent. acid. On this basis, treatment at the rate of 3,000 lb. per mil. gal. is equivalent to about \$12.50 per mil. gal. for acid alone. Omission of the concentration process, or use of the sulphur dioxide resulting from the burning of sulphur or pyrites directly may influence the cost.

The complicated apparatus necessary for operation and possibility of corrosion by the acid on materials ordinarily used in construction need consideration. Equipment is also required to recover the fat precipitated with the sludge. In the past this recovery has seldom proved remunerative, except on wastes containing more fat than is here present and except where the cost of sludge disposal is a factor.

CONCLUSIONS. The results on hand indicate that treatment of this sewage with acid results in a somewhat greater retention of fat. An apparent reduction in the oxygen demand over that resulting from plain sedimentation, while remarkable, is probably not real, being simply due to a retardation of decomposition by the sterilization of the bacteria present, the organic matter being left in solution. If thoroughly seeded with new bacteria, decomposition will again continue with renewed bacterial action. However, there appears the added cost of acid treatment and the cost of recovery of the grease, as well as the uncertainty of the price to be received for the grease recovered.

CHAPTER XV.

OXYGEN REQUIREMENTS.

GENERAL. For ease in comparison, the oxygen requirements are collected here under one head. The method of investigation is one recently developed by Dr. Arthur Lederer, described in detail in the May, 1914, issue of the Journal of Infectious Diseases.

METHOD OF PROCEDURE. The method is based on the addition in excess of definite quantities of saltpeter (sodium nitrate) and methylene blue to the samples of the sewage or effluent to be tested, followed by incubation for 10 days at 20 deg. C. The residual total oxygen is then determined. The saltpeter added is a standard solution of known strength. Extended observations have indicated that 2 molecules of the salt yield approximately 5 atoms of oxygen available for oxidation of putrescible organic matter in sewage liquid. The oxygen consumption is the difference between the residual oxygen after 10 days' incubation and the amount originally added. The period of 10 days was selected because experience has indicated that samples which hold out for that period may, for all practical purposes, be considered stable. The initial available oxygen in the crude sewage and tank effluents is frequently low enough to be of no practical importance, but in the sprinkling filter effluent it is a large proportion of the total oxygen demand, ofter exceeding

TABLE 110.

COMPARATIVE OXYGEN DEMAND AND SUSPENDED MATTER FOR CRUDE SEWAGES AT CENTER AVE. AND 39th ST.

Period 1914	Parts per Million			
	Biologic Oxygen Consumption		Suspended Matter	
	Center Ave.	39th St.	Center Ave.	39th St.
Jan. 14 to 31	990	130	467	138
Feb. 17 to Mar. 3	1030	120	453	75
Apr. 15 to 30	880	100	478	70
May	930	120	424	130
June	1010	130	444	195
July	1080	140	433	140
Weighted Average	990	130	444	135

it. The methylene blue serves as an indicator, the color disappearing when an insufficient amount of the saltpeter is used.

Up to May 1, 1914, two samples of crude sewage and of the effluents from each device were taken daily, the sewage samples being collected at 9 A. M. and noon or 1:15 P. M. and the effluents with proper allowance for the nominal detention period. Subsequently, samples were collected every two hours throughout the day (8 in all) and incubated. At the end of 10 days, the samples were mixed and the residual oxygen determined for the composite samples. In this way, much more representative results were obtained. Determinations were made on Monday, Wednesday and Friday every other week and on Tuesday and Thursday of the alternate weeks.

CRUDE SEWAGE. The oxygen requirements of the crude

TABLE 111.

COMPARATIVE REDUCTION IN OXYGEN DEMAND AND SUSPENDED MATTER FOR VARIOUS SETTLING TANKS.

Period 1914	No. Days	Biologic Oxygen Consumption—Parts per Million				Per Cent Reduction			Remarks
		Grit Chamber	Dortmund Tank	Emscher Tank	Chem. Precip.	Dortmund Tank	Emscher Tank	Chem. Precip.	
Jan. 14 to 31	5	990	...	880	...	...	11	...	......
Feb. 17 to Mar. 3....	5	1030	850	760	750*	18	26	22*	*4 days
Apr. 15 to 30	5	880	640*	630*	610*	22*	24*	36*	*4 days
May........	10	930	670	630	560	28	33	40	......
June........	10	1010	650	540	700*	35	47	33*	*7 days
July........	10	1080	640	560	570*	41	48	48*	*8 days
Weighted Av.	...	990	680	630	620	32	36	38	......
		Suspended Matter Parts per Million				Per Cent Reduction			
Jan. 14 to 31	5	467	...	210	...	...	55	...	......
Feb. 17 to Mar. 3....	5	453	178	170	111*	61	63	74*	*4 days
Apr. 15 to 30	5	478	157*	165*	138*	68*	67*	72*	*4 days
May........	10	424	162	153	81	62	64	81	......
June........	10	444	122	112	134*	73	75	70*	*7 days
July........	10	433	150	130	141*	65	70	69*	*8 days
Weighted Av.	...	444	150	148	118	66	67	74	......

NOTE. Samples of grit chamber effluent omitted on days when no tank sample was collected in figuring per cent reductions.

day sewage and the total suspended matter are given in table 110, with similar figures for the 39th St. sewage.

Measured by the relative oxygen demands, the heavy day sewage received at the Center Ave. testing station averages about 8 times as strong as the domestic sewage received at 39th St.

REDUCTION IN OXYGEN REQUIREMENTS BY SEDIMENTATION. The improvement in the oxygen consumption by sedimentation in various devices is summarized by months in table 111. Conditions of operation for the various tanks have been given in previous chapters. Comparison with the reduction in suspended matter shows that the reduction in oxygen demand is far below the reduction in suspended matter. An average decrease of 32 per cent. was indicated for the Dortmund tank, 36 per cent. for the Emscher tank, and 38 per cent. for the chemical precipitation tank. The corresponding reductions in suspended matter were 66, 67, and 74 per cent. respectively. Recent results were in general better than dur-

TABLE 112.

REDUCTION IN SUSPENDED MATTER AND BIOLOGIC OXYGEN CONSUMPTION BY ROTARY SCREEN ON CENTER AVE. SEWAGE.

July 8 to 30, 1914.

Date 1914 July	Suspended Matter Parts per Million		Dry Screen.	Biologic Oxygen Consumption Parts Per Mil.		Per Cent Reduction	
	Crude Sewage	Screen Effluent	Lbs. per Mil. Gals.	Crude Sewage	Screen Effluent	Susp. Matter	Bio. Ox. Cons.
8	489	434	454	1210	1100	11	9
10	330	301	238	900	890	9	1
14	400	375	210	1020	1050	6	3*
16	439	398	342	1180	1060	9	10
20	389	366	194	1060	1020	6	4
24	505	470	289	1120	1010	7	10
28	523	473	420	1180	1050	9	11
30	821	775	382	1090	1040	6	5
Average	487	449	316	1100	1030	8	6

* Denotes increase.

NOTE. Suspended matter in crude sewage is calculated from determination on effluent by addition of weight of dry screenings. Per cent reduction is based on this also.

ing the winter, perhaps because the method of sampling was more representative after May 1st. Although the operating conditions of the different devices were changed several times, these experiments indicate that on the Center Ave. sewage efficient sedimentation will reduce the oxygen demand from 25 to 45 per cent., with a reduction in suspended matter approaching 70 per cent.

REDUCTION IN OXYGEN REQUIREMENTS BY FINE SCREENING. To determine the effect of fine screening on the oxygen demand of the crude sewage at Center Ave., routine tests were made during July, 1914, on the effluent from the rotary screen. The results of these tests, with corresponding determinations of suspended matter (table 112) show the improvement in oxygen requirements by fine screening to be small, averaging about 6 per cent. for the 8 tests made. The reduction in suspended matter averaged 8 per cent. for the entire series, based on computed influent analyses. Use of actual suspended matter determinations on the influent showed an average reduction of only 3 per cent. This latter figure is low, and probably in error because of the difficulties in sampling.

REDUCTION IN OXYGEN REQUIREMENTS BY FILTRATION. Table 113 shows the results obtained by months on the sprinkling filter, fed by the Emscher tank. Up to April 1, 1914, the filter was operated at a net rate of yield of ¾ mil. gal. per acre daily, and thereafter to give a net yield of one mil. gal. For comparison, the grit chamber and Emscher tank figures are included.

The reduction in oxygen demand is very marked, averaging over 90 per cent. of the amount required by the crude sewage. Of this from 25 to 45 per cent. may be produced by the tank treatment. Although the total gross reduction in oxygen demand is large, the net demand or amount of oxygen which must be supplied from external sources is reduced even further, because the effluent contains a large part or all of the oxygen required for stability in the form of free oxygen, nitrites, and nitrates, all readily available. During May, June and July, 1914, the available oxygen in the filter effluent was more than sufficient for stability, or in other words, the relative stability was over 100. Treatment of the Center Ave. sewage on coarse grained or sprinkling filters up to rates of yield of one mil. gal. per acre daily, when preceded by thorough preliminary sedimentation is apparently capable of producing an improved effluent usually containing sufficient available oxygen to require little dilution for complete stability, and for days at a time containing an excess, being then completely stable.

TABLE 113.

COMPARATIVE REDUCTION IN OXYGEN DEMAND AND SUSPENDED MATTER IN EMSCHER TANK AND SPRINKLING FILTER.

Period 1914	No. of Days Sampled	Parts per Million						Per Cent of Original Requirements		Relative Stability
		Biologic Oxygen Consumption			Available Oxygen Sprinkling Filter		Net Oxygen Demand Filter			
		Grit Chamber	Emscher Tank	Sprinkling Filter	Free	Total		Emscher Tank	Sprinkling Filter	
Jan. 14 to 31......	2	1010	790	109	3.1	34	75	78	7	31
Feb. 17 to Mar. 3	5	1030	760	92	3.4	37	55	74	5	40
Apr. 15 to 30....	4	830	630	75	3.8	73	2	76	2	97
May............	10	930	630	68	2.2	84	16*	67	2*	100*
June............	9	1020	530	43	5.0	65	22*	52	2*	100*
July	9	1070	560	52	4.4	60	8*	53	1*	100*
Weighted Average	...	990	620	64	3.7	64	0	63	0	100
		Suspended Matter Parts per Million						Per Cent Reduction		
								Emscher Tank	Sprinkling Filter	Total
Jan. 14 to 31......	2	448	183	116	...	...	...	59	15	74
Feb. 17 to Mar. 3	5	453	170	109	...	...	...	62	14	76
Apr. 15 to 30....	4	462	138	167	...	...	...	70	6†	64
May............	10	424	153	128	...	...	...	64	6	70
June............	9	448	116	132	...	...	...	74	3†	71
July	9	427	133	135	...	...	...	69	1†	68
Weighted Average		439	142	131	...	...	...	68	2	70

* Denotes excess.
† Denotes increase.

CHAPTER XVI.

EXISTING SEWERS.

CITY AND PRIVATE SEWERS. The municipal sewers receiving waste from Packingtown and the Stockyards include those on Ashland and Center Ave., 39th St. conduit and two sewers on Halsted St. (table 114), which discharge into the east and west arms of the South branch (fig. 18). In addition there are a number of private outlets (table 115) as follows: Sulzberger Sons Co., Hine Bros., Swift & Co., Friedman Mfg. Co., Anglo-American Packing Co., Western Packing & Provision Co., Union Stockyards and Transit Co. (Morgan St.), and the Chicago reduction plant. Private sewers also enter from the Eagle Brewing Co., Hately Bros., Cold Storage, and from the Union Stockyards and Transit Co. filter plant. Robey St. sewer discharges into the west arm, but is practically wholly domestic in character. The 39th St. conduit receives the waste of the Brennan Packing Company. Several small houses on 39th place drain into the 39th St. sewer.

ANALYSES. Analyses have been made at intervals of various samples from the sewers on Ashland Ave., Center Ave., and Morgan St., as well as most of the other outlets mentioned. The results (table 116) show a very strong sewage, as a whole, particularly in Ashland and Center Ave., not only high in suspended matter, but also in oxygen consumed, indicating a sewage about 5 to 10 times as strong as the average normal sewage found at 39th St. testing station (table 116), and very much stronger than the sewage from Robey St.

The analyses of the sewage at 39th St. pumping station represent nearly an average domestic sewage, south of the Chicago river, with the exception of the loop district, which is slightly stronger.

The analyses of the Halsted St. sewers were of samples collected over a very short period. The south sewer appears weaker than the north. At other times, however, the sewage has appeared unusually strong, containing blood and other evidence of packing-house wastes.

The great variations in strength of the Center Ave. sewage at different hours of the day are shown by the results of a week's run in the fall of 1914 (fig. 19). Two-hour composite samples made up of equal portions collected every 15 min. were analyzed for suspended matter. Although slight rains occurred on Oct. 26 and 28,

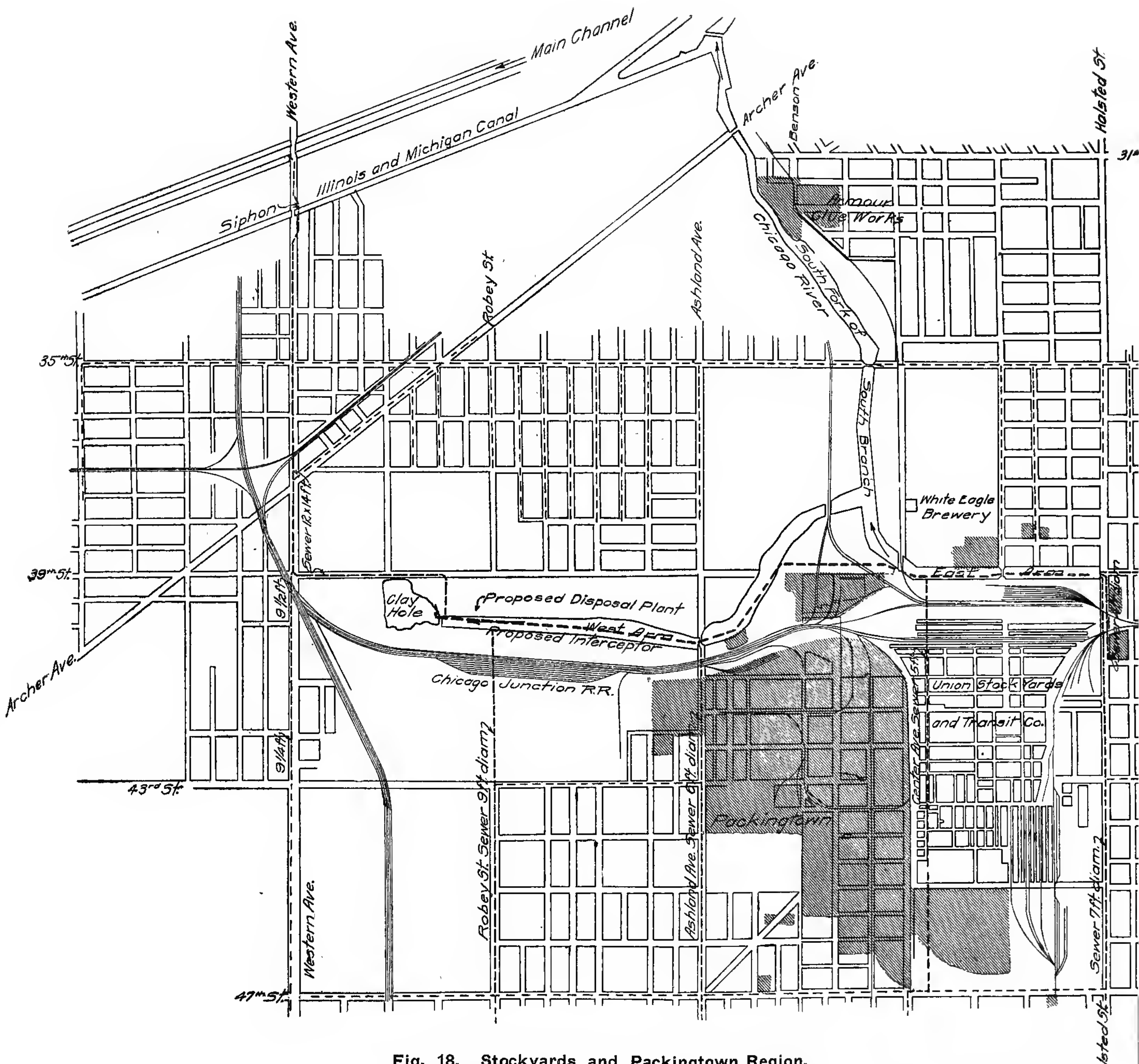

Fig. 18. Stockyards and Packingtown Region.

Sewers tributary to East and West Arms of South Fork of South Branch of Chicago River.

Note.—Red tint indicates area devoted to packing and allied industries. One alternative of proposed intercepting sewer is shown in red.

TABLE 114.

DATA ON MUNICIPAL SEWERS ENTERING EAST AND WEST ARMS OF SOUTH FORK OF SOUTH BRANCH OF CHICAGO RIVER.

Sewer	Size Diam. in Feet	Drainage Area Acres	Tributary Population Estimated 1914	Population per Acre 1914	Actual Flows, Cu. Ft. per Sec.		Remarks
					Dry Weather	Storm	
39th St. Conduit ‡	20	16,660	400,000	24	200°	1650°	Domestic sewage and flushing water from lake.
Halsted St.	7	1,200	61,700	48	25*	125*	Receives packinghouse waste.
Halsted St.	4	93					
Center Ave	5	660	27,000	41	32.1●	105	Receives packinghouse and stockyards waste.
Ashland Ave.	6	980	52,000	53	45†	115*	Receives packinghouse waste.
Robey St.	9	2,500	45,000	18	15	150	Practically domestic.

● Average flow for month 8 a.m. to 10 p.m.
† Estimated average day flow (8 a.m. to 10 p.m.).
* Estimated.
‡ Includes State St., Wentworth Ave., and Wallace St., sewers.
° Estimated. This omits flushing water from lake, which may vary from 1,000 to 2,000 cu. ft. per sec.

TABLE 115.

DATA ON PRIVATE SEWERS ENTERING EAST AND WEST ARMS OF SOUTH FORK OF SOUTH BRANCH OF CHICAGO RIVER.

Description	Size Diam. in Inches	Bank of River	Actual Flows Cu. Ft. per Sec.		Remarks
			Average Daily	Max. Observed	
Morgan St.	20	So.	1.9†	2.4†	Union Stockyards & Transit Co.
Western Packing Co.	..	No.	0.88*	1.18	Packinghouse waste, 4 outlets.
Anglo American.	..	So.	1.8	2.61	Packinghouse (1911).
White Eagle.	12	No.	0.2‡	0.5‡	Brewery.
Chicago Reduction Co.	..	So.	0.2‡	0.5‡	Plant recently rebuilt.
Friedman Mfg. Co.	..	So.	0.12	0.17	Butterine makers.
Swift & Co.	12	So.	0.76	0.91	Miscellaneous Connections.
Hine Bros. Co.	..	So.	0.2‡	0.5‡	Reduction and rendering.
Sulzberger Sons Co.	..	So.	0.5‡	1.00‡	Drainage from back of yards.

* Average of 9 hour observation on two outlets.
† Day hours.
‡ Estimated.

the test represents essentially dry weather conditions. For comparative purposes, composite discharge figures from fig. 20 have been added.

CONDITIONS NOT NEW. As far back as 1890, the analyses made by Prof. J. H. Long of the discharge of various sewers, including Ashland Ave., show a very strong sewage (tables 1 and 116). Altho his sampling extended over one month, the results agree very closely with those obtained by the Sanitary District in 1911 and 1913 (table 116).

GAGINGS. From time to time gagings have been made of the flow of the various outlets. The outlets of the two Halsted St. sewers were so inaccessible that no gagings were made. The 39th St. conduit receives domestic sewage and flushing water, as well as the discharge of the Brennan Packing Company. No samples were taken other than at the Brennan plant (appendix 7). All the industrial sewers have a very marked difference between day and night flow, the day flow being much larger, in distinction to the more uniform flow found in the purely domestic sewers (fig. 20).

SPECIAL GAGINGS. Special gagings were made on Center and Ashland Aves., and Robey St. in 1911, about the time of the extended gagings in Packingtown (chapter 2).

A weir was built in the outfall of the Center Ave. sewer below

TABLE 116.

ANALYSES OF SEWAGE FROM 39th ST., STOCKYARDS, PACKINGTOWN, AND OTHER SEWERS.

Results in Parts per Million.

Determinations	39th St.		Halsted St.		Morgan St.[3]	Center Ave., 1913		Ashland Ave.			Robey St.[7]
	1909 to 1912	1913	North[1]	South[2]		8 a.m. to 11 p.m. Day	11 p.m. to 8 a.m. Night	J. H. Long 1890 24 Days	Day[6]	Night[6]	
Nitrogen as											
Free Ammonia	9.1	8.6	28	19	...	22	...	...	20	18	29.6
Organic N.	7.8	6.6	260	10.4	...	79	...	...	73	34	8.4
Nitrites.	0.10	0.09	...	...	...	0.49	...	...	0.21	0.08	0.07
Nitrates.	0.38	0.24	...	...	...	3.04	...	...	1.97	0.86	0.31
Oxygen Consumed	43	37	257	60	202	268	...	429	245	70	51
Chlorine.	40	38	365	56	...	1100	...	1895	920	537	261
Alkalinity	212	198	340	222	...	291	...	...	358	237	464
Suspended Matter											
Total.	144	131	428	176	548	605	160	894	860	258	63
Volatile.	90	81	344	88	401	461	108	706	657	120	40
Fixed.	54	50	84	88	147	144	52	188	203	138	23
Fats.	23[8]	...	...	...	...	226[4]	123[4a]	...	...	...	...
	...	...	...	...	...	153[5]	...	...	...	...	...

[1]July 28, 1911, 4 hr.
[2]July 29, 1911, 4 hr.
[3]Ninety-five days in 1911.
[4]Eight days, winter, 8 a. m. to 8 p. m.
[4a]Eight days, winter, 8 p. m. to 8 a. m.
[5]Five weeks, April and May, 1914.
[6]Fourteen day samples, ten night samples, 1913.
[7]Three days, May 31 to June 3, 1911.
[8]Approximately, four months' record.

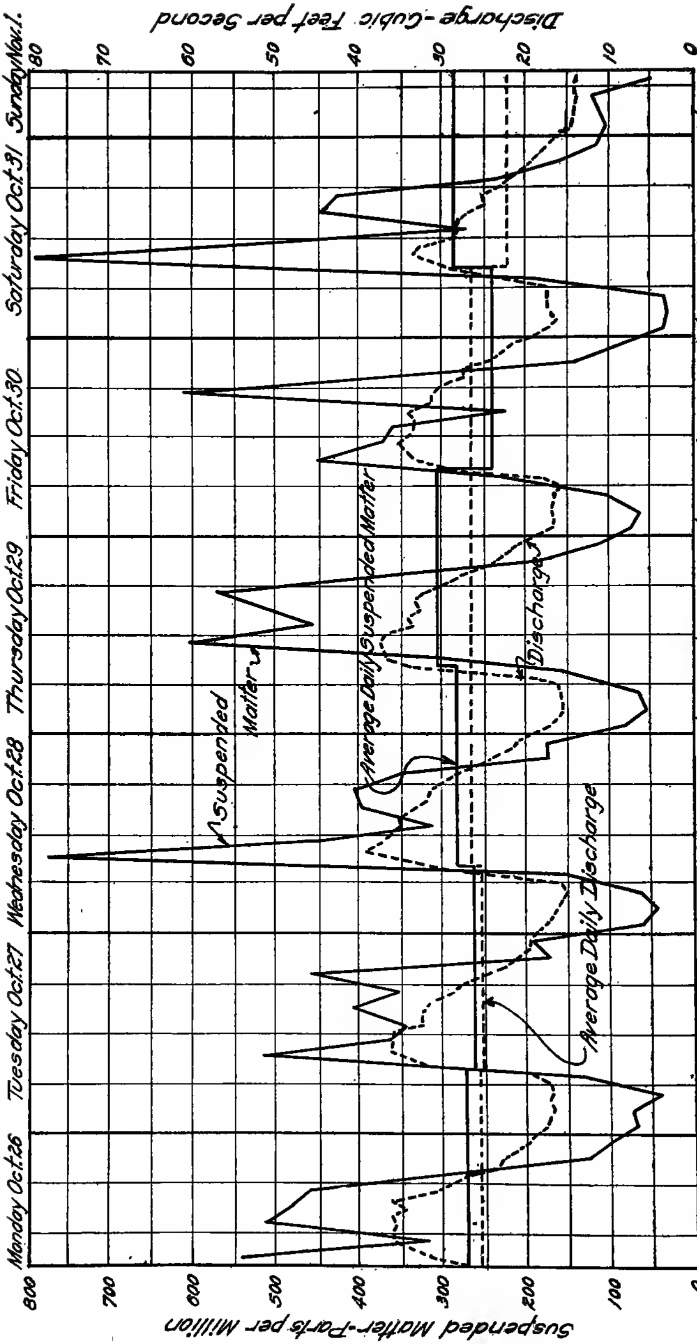

Fig. 19. Hourly Variation of Suspended Matter at Center Ave., 1914.
Note.—Average Daily Discharge is not for same period but is typical.

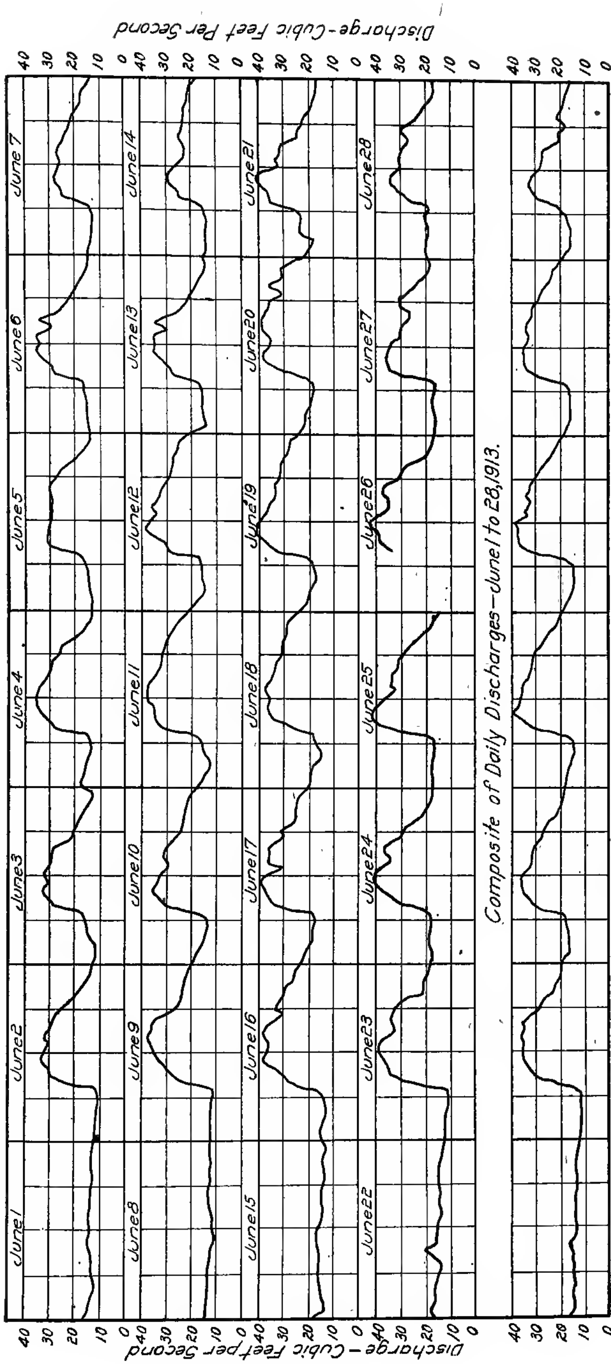

Fig. 20. Discharge of Center Ave. Sewer, June 1 to 28, 1913.

TABLE 117.

TEST OF CENTER AVE. SEWER.

May 16 to 18, 1911.

May	Period	Flow Cu. Ft. per Sec.	Suspended Matter P. P. M.
16	Noon to 8 p. m.	23.1	621
16	8 p. m. to 17, 8 a. m.	17.0	161
17	8 a. m. to 8 p. m.	25.3	649
17	8 p. m. to 18, 8 a. m.	16.8	149
18	8 a. m. to noon	28.8	759
Average for period 48 hours		21.1	402

the outlet of the Armour grease skimming basin, the gagings being given in table 117. The maximum flow was 30 cu. ft. per sec. over 2 hr., the minimum flow being 16 cu. ft. per sec. for 1 hr. At the time the testing station was placed in operation, a new weir was built at the sewer outlet and hourly readings were taken for about one year. The results are summarized by months on table 118. The average flow during this period between the hours of 8 A. M. and 10 P. M. was 29.0 cu. ft. per sec. and the average between 11 P. M. and 7 A. M., inclusive, was 16.4 cu. ft. per sec. The maximum discharge recorded was about 105 cu. ft. per sec. on May 20, 1913.

A weir was built in 1911 on the face of the outfall at Ashland Ave., the gagings being given in table 119. The maximum flow was 31.5 cu. ft. per sec. for 1 hr., and the minimum flow 18 cu. ft. per sec. for 3 hr. A few measurements, made in the fall of 1913, showed an average dry weather discharge of about 35 cu. ft. per sec. between 8 A. M. and 10 P. M., while the night flow dropped to from 25 to 30 cu. ft. per sec. A discharge of 80 cu. ft. per sec. was observed on Sept. 16, 1913.

A weir was built in the outfall of the Robey St. sewer, about 15 ft. south of the river bank, the gagings being given in table 120. The maximum flow was 11.7 cu. ft. per sec. for 1 hour and the minimum flow 9.4 cu. ft. per sec. during 2 hours. On Aug. 12, 1911, one reading of 37.2 cu. ft. per sec. was obtained, immediately after a heavy rain. Since then the weir has been carried away twice by storms, but each time has been rebuilt. Continuous records with a Bristol recording water level gage have been kept since Sept. 4, 1912. Table 121 shows the results for 1913, averaging 13.2 cu. ft. per sec. with a maximum flow of 135 cu. ft. per sec.

PACKINGTOWN SEWERS. The sum of the discharge of the various individual plants examined during the period of four months

TABLE 118.

DISCHARGE OF CENTER AVE. SEWER.

Date	Cubic Feet per Second									Remarks
	Average Week Day			Max. Week Day		Min. Week Day		Maximum Rate One Hr.	Sunday Flow Average 24 Hrs.	
	8 a.m. to 10 p.m. Inclusive	11 p.m. to 7 a.m. Inclusive	24 Hrs.	8 a.m. to 10 p.m. Inclusive	24 Hrs.	8 a.m. to 10 p.m. Inclusive	24 Hrs.			
1912										
November	27.1	14.0	22.2	30.6	24.6	24.7	20.9	36.0	13.0	10 days
December	26.4	14.4	22.4	31.9	26.8	20.0	18.6	47.7	11.4	19 days
1913										
January	27.8	14.3	22.8	33.8	30.0	18.3	16.4	44.0	13.0	......
February	26.2	13.4	21.3	31.1	24.8	27.7	18.3	41.7	12.0	......
March	27.0	14.1	22.2	34.0	30.1	20.7	17.8	60.6	16.7	30 days
April	27.6	15.7	23.0	35.6	30.3	21.4	19.1	44.6	13.3	......
May	28.2	16.2	23.7	50.8	42.5	20.0	17.2	105.0	11.6	......
June	30.3	16.8	25.0	34.8	29.6	23.8	20.3	42.7	14.8	......
July	32.1	19.9	27.6	42.5	38.5	23.8	20.5	48.7	16.0	......
August	31.6	19.4	26.8	36.8	31.1	25.7	23.6	57.0	19.0	......
September	31.8	20.1	27.8	42.8	38.4	25.4	20.8	57.4	15.8	......
October	31.5	16.7	26.0	35.0	27.0	27.0	25.7	46.4	13.1	16 days
Average	29.0	16.4	24.3	37.2	32.0	23.0	19.7	54.0	14.3	......

TABLE 119.

TEST OF ASHLAND AVE. SEWER.

May 18 to 20, 1911.

May	Period	Flow Cu. Ft. per Sec.	Suspended Matter P. P. M.
18	1 p. m. to 6 p. m.	29.2	921
18	6 p. m. to 19, 8 a. m.	19.0	325
19	8 a. m. to 8 p. m.	28.9	849
19	8 p. m. to 20, 8 a. m.	18.1	277
20	8 a. m. to 1 p. m.	26.9	834
Average for period 48 hours		23.2	641

in 1911, totaled up to between 25 and 30 cu. ft. per sec. Comparison with the gagings given in tables 117, 118 and 119 would indicate (table 122) that the packing house flow is a very large proportion of the total flow of both Center Ave. and Ashland Ave. sewers.

The network of sewers in Packingtown and the Stockyards has been indicated in fig. 3. Many of these sewers are overloaded, particularly at time of rain. Even the Center Ave. sewer is inadequate at times of heavy rain, backing up nearly to the surface of the ground near 47th St. At time of storm the Hammond plant closes a sluice gate to prevent their private sewer backing up, and starts a centrifugal pump to throw storm water into the sewer.

Considerable rebuilding is undoubtedly desirable to reduce the multiplicity of small lines, improve sewerage and drainage facilities and relieve flooding at storms.

WEST THIRTY-NINTH ST. AND WESTERN AVE. CONDUIT. This conduit is elliptical in shape, 12 by 14 ft. on diameters, built of concrete, with a flow depth of about 10 ft. It extends from the west end of the west arm north to West 39th St., thence westerly to Western Ave., and northerly along Western Ave. to the Main Channel. The conduit was opened in the spring of 1911, and has been in service ever since. The flow depends on the difference in elevation of the west arm and the Main Channel. This is very variable and at times is zero or even reversed. In June, 1914, an examination was made of this conduit by a diver. At the inlet from 2 to 3.5 ft. of deposit was found. Deposits from 1.5 to 2 ft. deep occurred at the south manhole, from 3.5 to 0.5 ft. deep in the siphon under the I. & M. Canal, the major portion being only 0.5 ft. deep, and from 3 to 4 ft. north of the north manhole. At the outfall at the Main Channel, a deposit of 1.5 to 2 ft. was found. At the inlet end, considerable rubbish, particularly water-logged wood, was noted.

TABLE 120.

TEST ON ROBEY ST. SEWER.

May 31 to June 3, 1911.

Date	Period	Flow Cu. Ft. per Sec.	Suspended Matter P. P. M.
May 31	4 p. m. to 12 Mid.	11.0	109
31	12 Mid. to 1, 8 a. m.	11.0	92
June 1	8 a. m. to 4. p m.	10.1	53
1	4 p. m. to 12 Mid.	9.8	70
1	12 Mid. to 2, 8 a. m.	9.8	38
2	8 a. m. to 4 p. m.	10.8	61
2	4 p. m. to 12 Mid.	10.1	57
2	12 Mid. to 3, 8 a. m.	10.1	27
3	8 a. m. to 2 p. m.	10.1	63
Average for period 70 hours		10.3	63

In general, the deposits were soft, black in color, with an oily or tarry odor, containing 66.8 to 92.3 per cent. moisture, and 57 to 67 per cent. fixed matter. Both fats and nitrogen are low. The loss of available cross-section has been around 15 per cent. at the stage of water in March and April, 1914.

Flow measurements with a current meter indicated from 67 to 76 cu. ft. per sec., with average velocities in the flow section of 0.65 to 0.83 ft. per sec. These are depositing velocities for the heavier material in suspension. The operation of the pumps at 39th St. had very little influence on the flow, which appears to be largely from Ashland Ave., Robey St. and Western Ave. Means should, therefore, be considered of increasing the velocity of flow through the conduit. The reduction in cross-section in the siphon from the full section of 115.8 sq. ft. (with flow line at elev. —1.0) to 85.2 sq. ft. causes an increase of velocity of 35 per cent. on gross areas, and about 15 per cent on net areas. This difference in velocities has, therefore, served to keep the siphon free from all but 6 inches of deposit. Evidently velocities are near the critical point for deposit in the siphon. Hence, velocities of 1 ft. per sec. and over appear essential.

Under present conditions it does not appear worth while to clean out the conduit, as deposits would only form again. As further deposits in forming will decrease the cross-section and increase the velocity, it is hardly probable that much more will form. Increase in flow and other alternatives for remedying existing conditions are discussed in chapter 17.

PRECIPITATION RECORDS. An automatic rain gage has

been maintained at the testing station since November 1, 1912, and the daily precipitation is indicated in table 123. The figures are from 12 noon on the previous day to 12 noon on the date recorded.

TABLE 121.

DISCHARGE OF ROBEY ST. SEWER.

Date 1913	Cubic Feet per Second			Remarks
	Average Daily	Maximum Daily	Maximum Hourly	
January	13.8	22.3	25.6	15 days only.
February	15.2	27.2	62.6	....
March	18.6	32.6	40.7	23 days only.
April	15.8	32.1	36.6	....
May	17.3	82.6	135.0	....
June	11.7	15.2	53.3	....
July	12.1	31.0	88.0	....
August	11.2	17.7	81.5	....
September	11.6	18.4	49.3	....
October	11.4	14.6	26.9	....
November	11.2	15.7	40.7	....
December	10.2	11.8	13.8	....
Average or maximum	13.2	82.6	135.0	....

TABLE 122.

COMPARISON ON FLOWS IN PACKINGTOWN AND IN SEWERS ON ASHLAND AND CENTER AVES., 1911.

Description	Flow in Cu. Ft. per Sec.	
	Day 8 a.m. to 8 p.m.	Night 8 p.m. to 8 a.m.
Center Ave. Sewer	25.7	16.9
Ashland Ave. Sewer	28.3	18.5
Center Ave. plus Ashland Ave.	54.0	35.4
Packingtown computed total	31.7	12.2

TABLE 123.

PRECIPITATION DATA—CENTER AVE. TESTING STATION.

Daily Record of Rainfall in Inches.

Day	1912		1913												1914								
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	.19	0	0	0	.09	0	0	0	0	.03	0	.11	0	0.47	0.42	0	0.03	0.52	0	0.08	0.09	0	0.35
2	0	.26	0	0	T	0	0	0	0	0	0	0	0	T	0	0	0	0	0	0	0	0	0.29
3	0	0	T	0	0	.10	0	0	0	0	0	0	0	T	0.03	0	0	0	0	0	0	0	0
4	0	.09	0	0	.06	.13	0	0	.09	0	0	0	0	0	0.10	0	0	0	0.23	0.45	0	0	0
5	.10	.18	0	0	.05	0	.50	0	0	0	0	.23	0	0	0	0	0	0	0	0.86	0	0	0
6	.68	0	.07	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0	0.12	0.05	0.05	0	0	0.30
7	0	0	.22	0	0	0	0	0	0	0	0	.06	0	0.02	0	0.09	0.04	0	0.53	0.23	0	0	0
8	0	0	0	0	0	0	0	0	0	.77	.05	.09	.09	0	0	0	T	0	1.00	0	0	0	0.16
9	0	0	0	0	0	.42	0	0	.74	0	0	.01	0	0	0	0	0	0.01	0	0	0	0	0
10	0	0	0	0	0	.42	T	0	0	.13	0	0	0	0	0	T	0	0	0	0	0	0.23	0
11	0	0	.04	0	0	T	0	0	0	.44	0	.41	0	0	0	0	0.02	0	0.72	0.01	0	0.62	0.17
12	.25	0	0	0	0	T	0	0	0	0	0	0	0	0	0	0.01	0	0	0.35	0	0	0	0
13	.21	0	0	0	0	0	1.24	0	0	.01	0	0	0	0	0	0	0	0	0	0	0	0.59	0
14	0	0	0	0	....	0	.01	0	1.02	.48	0	0	.04	0	0	0	0	0	0	0.21	0.15	0.20	0
15	0	0	0	0	....	0	0	0	1.10	0	0	0	0	0	0.07	0	0	0	0	0	0	0	0.15
16	.01	0	0	0	....	0	0	T	.25	0	.52	0	0	0	0	0.07	0	0	0	0	0	0.11	0
17	0	.50	.03	.03	....	0	0	0	0	0	.53	.50	0	0	0	0	0.11	0	0	0	1.19	0.17	0
18	0	0	.04	0	....	0	0	0	.02	0	T	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	....	0	0	0	0	.40	0	0	0	0	0.18	0	0	0.01	0	0.09	0	0	0
20	0	0	.33	0	....	0	1.28	0	.06	0	.15	.01	0	T	0.02	0	0	0	0	0	0	0.13	0
21	0	0	0	.77	....	0	.22	.65	0	0	.01	0	0	0	0	0.01	0	0	0	0	0	0	0
22	0	0	0	.53	....	0	0	T	0	.23	0	0	.18	0	T	0.04	0.03	0	0	0.43	0	0	0
23	0	0	.37	0	....	0	0	0	.07	0	0	.36	0	0.31	0	0.11	T	0	0	0	0	0	0
24	0	0	0	0	....	0	.10	0	0	0	0	0	0	0.10	0.25	T	0	0	0	0	0.18	1.10	0
25	.10	0	0	0	.06	.30	.02	.15	0	0	0	0	0	0	0	0	0.03	0.14	0	1.14	0.18	0	0.09
26	0	0	0	.20	.02	.19	1.76	0	0	0	0	0	.08	0	0.18	0	0.41	0	0	0.05	0	0	0
27	0	0	0	.13	0	0	.10	0	0	0	.01	.27	.02	0	0	0	0.60	0.04	0	0.03	0	0	0
28	0	0	0	T	0	0	T	0	0	0	0	.07	0	0	0	0	T	0.10	1.00	0	0	0	0
29	0	0	0	....	0	0	0	0	0	0	.16	0	.32	0	0.12	....	0.11	T	0	0	0	0.78	0
30	0	.08	0	....	0	0	0	0	0	0	.01	.16	.09	0	0	....	0.21	0.01	0.26	0	0	0	0
31	....	0	0	....	0	....	T	...	.01	.01	....	.01	....	0	1.03	....	0	....	0	....	0	0	....
Total	1.54	1.11	1.10	1.66	....	1.56	5.23	0.80	3.36	2.47	1.44	2.29	0.82	0.90	2.40	0.43	1.59	0.95	3.13	3.63	1.79	3.93	1.51

Note. T denotes trace.

CHAPTER XVII.

PROJECTS.

OBJECT. The purpose of the investigation has been two-fold, first, to learn how to relieve the load upon the Main Channel coming from the organic wastes of this industry, and, second, how to remove the local nuisance from Bubbly Creek. Various projects have been considered, including the filling of Bubbly Creek, but all require the treatment of the industrial wastes and a certain amount of sewerage construction and revision to collect the sewage from industrial plants for treatment.

SUGGESTED IMPROVEMENT. The controversy now pending with reference to limitation of the diversion of water to be withdrawn from Lake Michigan by The Sanitary District of Chicago has made it difficult to determine the final solution of the problem considered in this report. However, The Sanitary District has taken the position that the question of disposal of the industrial wastes is distinct and separate from that of disposing of human sewage, and that in accordance with the organic law the industrial wastes must be treated, irrespective of the outcome of the controversy. Ultimately the complete treatment of the industrial wastes seems necessary, in order to relieve the great oxygen demand of such wastes. On the other hand, the first step is to remove the settling suspended matter, by screening and sedimentation. This is essential in any case, and is needed at once. Whatever sewerage construction is planned in connection with the removal of the settling suspended matter and otherwise must be flexible enough to fit every contingency.

The diversion from the proposed Center Ave. sewer of the industrial wastes from Packingtown and the Stockyards seems desirable to give the municipal authorities the greatest flexibility in meeting future conditions. Whatever be the diversion of water allowed from Lake Michigan, this plan lends itself readily to future development. It reduces the amount of domestic sewage to be mixed with the industrial wastes, relieves over-burdened sewers, and concentrates the waste of an industry for the most efficient handling.

POLICY. At present, the only course open to the Sanitary District is to continue the dilution of domestic sewage, and as far as possible to secure the treatment of industrial wastes, in order to comply with the intent of the organic law. The handling of the in-

dustrial wastes is immediately contemplated, and the suggestions of the steps to be undertaken are embodied in this chapter in accordance with the investigations outlined herein. Who shall bear the burden of cost is yet to be determined and adjusted.

In the ultimate treatment of the industrial wastes from the Stockyards and Packingtown, biological works seem necessary Space is lacking for such works in the immediate vicinity of the Stockyards, and would need to be sought elsewhere, undoubtedly to the westward. The problem involves many ramifications both legal and otherwise, that have not been considered in detail in this report. It would involve the construction of a long intercepting sewer along city streets and private right of way, the acquirement of large areas of land, and the construction and operation of a pumping station, sprinkling filters and collateral works.

RECOVERIES. From the standpoint of recoveries, each individual house or firm should endeavor to retain or use all material of value before the sewage reaches the sewer outlet of the house or firm. Many already do so, but some of the smaller houses do not.

If not already installed, this means the use of reduction tanks, the saving of tankage, the evaporation of tank water, and constant care in avoiding careless handling of waste, particularly paunch manure. Adequate grease skimming basins should be installed. Before the sewage passes to the municipal sewer, fine screening is desirable, followed by sedimentation. Co-operation among the houses would materially help, as some have greater facilities than others for use of recoveries in by-products.

TREATMENT. From the standpoint of treatment of the Center Ave. sewage and Packingtown waste, several steps or degrees of efficiency are open:—

1. Fine screening.
2. Fine screening in combination with sedimentation.
3. Fine screening, in combination with sedimentation, followed by biological treatment on sprinkling filters, and secondary sedimentation.

While our screening tests indicate a greater removal at the individual plant or outlet than at the community outlet, the improvement thereby alone does not appear sufficient. It is important that all the settling suspended matter be removed. For this, sedimentation appears needful. Screening is helpful in removing light organic matter, relatively slow to decompose, which binds the sludge together and by rising tends to produce large amounts of floating scum.

The problem of the Stockyards is slightly different from Pack-

ingtown, in that the sewage discharged contains principally hay, mud, manure, and urine. From the Stockyards the sewage can readily be collected as a whole and kept distinct from Packingtown in the preliminary treatment. Screening and sedimentation appear needful at present. When the installation of biological treatment is made, as in the case of Packingtown, the same general circumstances would govern.

Screening and sedimentation plants, whether individual or collective, should be designed so that the effluent can be readily diverted and connected with biological works.

Biological treatment in general requires far more space than is available at the Yards or Packingtown. Consequently, a plant would be located at some distance, perhaps outside the western limits of the city, to the south of the Main Channel. A long intercepting sewer would be needed, in the operation of which preliminary screening and settling would be advantageous, in avoiding deposits from a sewage so heavily laden with settling suspended matter.

ASSUMPTIONS. In all the projects considered, the pumpage from 39th St. has been assumed to enter the East Arm, as heretofore. The other municipal and private sewers from Halsted St. west to Robey St. are included in the various projects as therein outlined. A description of the various sewers is given in Chapter XVI.

In studying the situation from the standpoint of treatment of industrial waste, the assumption has been made that the present load will not materially increase in the near future. Inspection of the kill in Packingtown (fig. 1) shows practically no increase since 1902. With the growth of other packing centers, the improvements in the industry, and the increasing attention given to details through Federal and State supervision, this does not seem unreasonable.

FILLING BUBBLY CREEK. From the sanitary standpoint the filling-up of Bubbly Creek (i. e., the West Arm of the South Fork of the South Branch of the Chicago River) would be desirable, altho mere filling alone would simply transfer the nuisance from one locality to another. With suitable treatment of the industrial wastes, it is entirely proper that this dead arm be filled and that the ground area be used as a site for sedimentation tanks.

If the City of Chicago requires facilities for water transportation at its reduction plant, the fill can commence just west and south of that property, continuing past Ashland Ave. to the west end of the West Arm. If the city will abandon water access, the fill can be extended to the Forks.

For years the West Arm has served as a crude settling basin

retaining settling material. To fill it up without provision for settling suspended matter, would transfer the sludge to other localities, and cure one nuisance to create another elsewhere. Hence any scheme involving the filling of the West Arm should include certain requirements to protect the Main Channel and appurtenances of The Sanitary District of Chicago.

The points to be kept in mind are as follows:

1. The flow in the West 39th St. conduit should be increased. This may be done by the introduction of the Robey St. sewer and sewage from the east thereof, including Stockyards and Packingtown.
2. The sewage from the Stockyards and Packingtown should be treated as herein outlined.
3. A portion of the bed of the West Arm should be reserved for a sedimentation plant for the Stockyards and Packingtown project.
4. Incidentally (in connection with 2), the sewers of Packingtown and the Stockyards should be remodelled to keep industrial sewage out of the proposed Center Ave. sewer.

The areas to be recovered between the points stated are as follows:

A.	End of West Arm to Ashland Ave.	11.5 acres.
B.	End of West Arm to W. 39th St.	16.5 acres.
C.	End of West Arm to Forks	24.3 acres.

The amount of fill required up to elevation +8.0, C. C. D., for the entire West Arm, west of the Forks is 900,000 cubic yards.

The amount of fill required up to elevation +8.0, C. C. D., for the West Arm west of the City reduction plant is 600,000 cubic yards.

If 6 acres be left open for the sedimentation plant, the fill required up to elevation +8.0, C. C. D., west of the reduction works is reduced to 400,000 cubic yards.

The material for filling will be available in part from the construction of the new Center Ave. sewer, from the excavation for the intercepting sewer proposed herein and from the excavation for the sedimentation tanks. The balance can be furnished by dumping ashes and excavation from other sources.

Should the owners of the abutting property desire, bridges at grade can be built across the West Arm at sufficient intervals to provide means for shifting freight, etc.

AREAS TO BE RESERVED. For treatment by sedimentation of all the sewage collected from Halsted St. to Robey St., inclusive, about 8 acres would be required for tanks and 7.5 acres for sludge

beds, on a basis of population estimated for 1922, making a total of 15.5 acres out of 16.5 acres available, if the Creek is filled to W. 39th St. For extensions, eventually the entire area reclaimed would appear inadequate.

For treatment by sedimentation of the Stockyards and Packingtown wastes alone, with a small amount of domestic sewage, about 6 acres are required at present for tanks and sludge drying beds. Greater area might be required later, possibly not over 3 acres additional.

PROPOSED SEWER TO REPLACE EXISTING CENTER AVE. SEWER. Mr. C. D. Hill, the Engineer of the Board of Local Improvements, has under consideration a sewer on the general line of Center Ave. which will materially change sewerage conditions in Packingtown. This will discharge about 100 feet west of the Center Ave. bridge, with an outlet 11 feet in diameter, and an invert at elev. —4.0 C. C. D. The grade will be 0.03 per cent. His plan includes intercepting the existing Center Ave. sewer south of 47th St., as well as the present sewers on Ashland Ave., Halsted St. and Wallace St., south of 52nd St., and the branch of the Robey St. sewer on Ashland Ave. south of 68th St. About 1 square mile south of 87th St. is also to be made tributary. The total drainage area will be about 4,500 acres, on which reside at present a population estimated at about 150,000. The construction of this sewer will reduce the flow in the present Center Ave. sewer to that coming from the Stockyards proper and a few packing houses. The flow in the other sewers affected will also be reduced. Unless the sewers in Packingtown are remodelled, about one-half of the wastes would enter the new sewer, as it would cut all the sewers now entering the existing Center Ave. sewer from 47th St. north. Our estimates are based on the conditions which will exist when the proposed sewer is completed, and the portions of flow diverted to it which now enter the Ashland Ave., Halsted St., Wallace St. and Robey St. sewers, as above stated.

SEWERS REQUIRED. The sewerage requirements hinge largely on the policy of treatment adopted. Out of four alternatives described herein there are at least two clear cut projects which appear entirely feasible.

I. Project I assumes that all the wastes are treated by screening and sedimentation at the points of origin. A sewer is required across the present creek from Robey St. to the entrance of the present W. 39th St. conduit, and an interceptor from the new Center Ave. sewer west to the W. 39th St. conduit. The West Arm can then be filled up. As the treatment of the industrial waste at the

point of origin to the degree required may be difficult on account of lack of space, this project does not appear wholly desirable.

II. Project II assumes that all the wastes are treated by screening at the point of origin and collected by an intercepting sewer to a community plant in Bubbly Creek for settling. A sewer is required from Robey St. to the entrance of the present W. 39th St. conduit, with an interceptor running along the south side of the East and West arms from Halsted St. to the sedimentation plant, the effluent of which would discharge into the West 39th St. conduit. Project II is based on keeping the industrial wastes out of the proposed Center Ave. sewer and diverting them into the Ashland Ave. by building certain trunk lines east and west in Packingtown. This project appears decidedly feasible.

III. Project III. assumes the undertaking of treating both industrial and domestic sewages at the present time. It then becomes possible to collect all the sewage from Halsted St. west to Robey St. into a common plant for settling, assuming the screening done at the point of origin. This, however, would require a very large area. The space available in Bubbly Creek west of W. 39th St. would not be adequate after 1920 or thereabouts. Moreover, this does not shape readily to future extension, particularly if the diversion allowed by the government is low.

IV. Project IV assumes that all industrial wastes are treated at the point of origin by individual screening and settling plants. A sewer would be built across Bubbly Creek from Robey St. to the entrance of the West 39th St. conduit, and the Ashland Ave. sewer would be diverted to the east. The West Arm could then be filled up. This, however, does not appear feasible, not only for the reason given under I, but also because the W. 39th St. conduit would sludge up and be productive of nuisance, the combined low flow of Robey St. and Western Ave. sewers being entirely inadequate to maintain scouring velocities.

From the standpoint of ease of extension, protection of W. 39th St. conduit, and future provision for further treatment to the westward, project II appears decidedly desirable and worthy of close study. Project III is less meritorious, including necessarily treatment of more domestic sewage and being less flexible both at present and in the future.

PACKINGTOWN SEWERS. In general, the impression is current among representatives of the packing houses that the existing patch-work sewer system in Packingtown is largely inadequate for present needs and unable to cope with heavy rains without flooding. As there are comparatively few cellars, this is not so troublesome as

might otherwise be. The houses draining into the Center Ave. sewer, particularly the Hammond plant, are seriously bothered, as the Center Ave. sewer is too small to handle heavy rainfalls. While our estimates for remodelling Packingtown sewers include an amount, stated in each case, for new sewers, these are merely trunk sewers. The estimates do not include any cost for rebuilding individual systems or for new connections to the proposed sewers. For an adequate estimate on the cost of that work a very detailed underground survey would be required, and considerable planning and study to figure out ways and means to tap and remodel a network of sewer pipes, many unknown, preserve sewerage facilities and rebuild on streets, constantly in use and frequently too narrow for ordinary traffic.

ESTIMATES. The estimates given herein are preliminary estimates, with due regard to local conditions, but are not based on any extended surveys or actual designs. They are approximate, prepared primarily to indicate the expenditures required to meet different alternatives of sewerage and treatment. In no case is any allowance made for legal, engineering, land or right of way expense.

Provision is made in the estimates for treatment only for a flow based on present conditions, assuming however that the Center Ave. sewer is built and the adjacent sewers relieved. No allowance is made for capacity to care for any growth in the immediate future, for reasons already stated.

SEWERAGE PROJECTS. Four sewerage projects are suggested, in addition to the remodelling of the sewers in the Yards and Packingtown.

In these, unless otherwise stated, the proposed Center Ave. sewer is assumed to be built with the changes previously noted, which will reduce the dry weather flow in most of the contributory sewers.

A. The Robey St. sewer can be connected to the entrance of the West 39th St. conduit by a 9 ft. circular sewer, about 800 ft. long, of which at least 150 feet would be carried on piles. This would cost about $35,000. The Ashland Ave. sewer can be extended easterly about 2,600 feet to the East Arm at or near the Forks. This would be a 6 ft. circular sewer, costing about $40,000.

The fault of this project is that sufficient dry flow would not be assured to maintain scouring velocities in the West 39th St. conduit.

B. A gravity interceptor can be constructed from Halsted St. west to the inlet of the West 39th St. conduit. All the sewers dis-

charging into Bubbly Creek would be tapped, with the exception of the proposed Center Ave. sewer. The dry flow and a portion of the storm flow could be handled. This requires about 2,190 lin. ft. of 5½ ft. circular sewer, 3,560 lin. ft. of 6 ft. circular sewer, 2,580 lin. ft. of 7½ ft. circular sewer, 800 lin. ft. of 8 ft. circular sewer, with a crossing of the West Arm, a siphon under the proposed Center Ave. sewer and other appurtenances, at a total cost around $150,-000.

C. A gravity interceptor can be constructed from Halsted St. west to the inlet of the West 39th St. conduit, at an elevation low enough to tap the proposed Center Ave. sewer. An overflow weir can be provided at Center Ave. to care for excess storm flow. The sewer would follow around the south bank of Bubbly Creek, requiring about 2,190 lin. ft. of 5½ ft. circular sewer, 510 lin. ft. of 6 ft. circular sewer, 3,050 lin. ft. of 10½ ft. circular sewer, 2,580 lin. ft. of 11 ft. circular sewer, and 800 lin. ft. of 12 ft. circular sewer, with a crossing of Bubbly Creek, and other appurtenances, at a cost of $230,000.

D. This project is similar to C, except that the interceptor would cross Bubbly Creek on the line of West 39th St. and follow West 39th St. to the conduit near Robey St. This necessitates the extension of the Ashland Ave. and Robey St. sewers across Bubbly Creek. At times of storm, the interceptor would probably flow under head. An overflow weir can be provided at Center Ave. to care for excess storm flow. This project includes about 2,190 lin. ft. of 5½ ft. circular sewer, 510 lin. ft. of 6 ft. circular sewer, 2,540 lin. ft. of 10½ ft. circular sewer, 2,600 lin. ft of 11 ft. circular sewer, 640 lin. ft. of 12 ft. circular sewer, in addition to 3 crossings of Bubbly Creek, the extension of Ashland Ave. and Robey St. sewers and miscellaneous work, at a cost of $250,000.

To prevent deposits in the intercepting sewer, under projects C and D, occasional flushings by a small screw pump would be of service. With a capacity of say 200 cu. ft. per sec., electrically driven, this would cost about $30,000. installed.

Of these projects, B appears most practicable, particularly because all the Stockyards and Packingtown wastes would be diverted from the proposed Center Ave. sewer.

COST OF SEWERAGE PROJECTS. The cost of the various sewerage projects described may be summarized in a preliminary way as follows, exclusive of engineering, right of way, or land charges.

A. For the connection of Robey St. to the West 39th St. con-

duit and for carrying Ashland Ave. east to the East Arm of the South Fork, approximately $75,000.

B. For the complete interception of all sewers from Halsted St. to Ashland Ave. and Robey St., with the exception of the proposed Center Ave. sewer and the portions of existing sewered areas diverted to it, and including the diversion of all packing-house wastes to Ashland Ave., approximately $275,000.

C. For the complete interception of all sewers from Halsted St. to Robey St. into West 39th St. conduit, following a route along the south bank of the East and West Arms of the South Fork, approximately $230,000.

If the packing-house wastes be diverted to Ashland Ave. for separate treatment, this cost will be increased to $355,000. If the pumping station be added, these figures would be increased by $30,000.

D. For the complete interception of all sewers from Halsted St. to Robey St. into the West 39th St. conduit, following a route along West 39th St., with branch lines to existing sewers, approximately $250,000.

If the packing-house wastes be diverted to Ashland Ave. for separate treatment, this cost will be increased to $375,000.

If the pumping station be added, these figures would be increased by $30,000.

COST OF TREATMENT.

SCREENING. Individual screening apparatus for individual firms in the Stockyards and Packingtown region will require a total expenditure of approximately $150,000. This estimate does not include buildings or any duplicate or reserve installation. It covers only screens, motors, and foundations with a small allowance for sewer connections. In many cases existing buildings would serve, in others new buildings would be required. Collective screening at the main sewer outlets will be less costly, but not quite so effective on account of the breaking down of material in transit. Individual screening will, however, keep all material recovered on the premises where produced.

SCREENING PLUS SEDIMENTATION. Individual screening plus collective settling appear feasible, as well as collective screening and settling. Probably slightly better results can be obtained with the former, altho the total cost will be somewhat higher. Assuming the new Center Ave. sewer built, and the adjacent sewers relieved, as previously noted, for the treatment works to handle the

sewage from Halsted St., Morgan St., the old Center Ave., Ashland Ave., and private sewers, the cost of a sedimentation plant with collective screening would be around $600,000, exclusive of legal, engineering, land, and right of way, expenses. Omission of the collective screening will reduce this to $560,000. In addition to the costs purely for treatment, remodelling the sewers in Packingtown to divert to Ashland Ave. will cost roughly around $125,000.

To collect the sewage from Halsted St. and along the river bank to Ashland Ave., thence to the plant, with discharge to the West 39th St. conduit, and the diversion of Robey St. into the same conduit will cost about $150,000. No account is taken of the proposed Center Ave. sewer.

BEST PROJECT. If any one project can be called best of the alternatives suggested, it is the one shown in red on fig. 18. This comprises an intercepting sewer largely for industrial wastes from Halsted St. to the West Arm, the diversion of all Packingtown from Center Ave. to Ashland Ave., fine screening at the individual houses or firms, sedimentation at the community outlet with a plant built in Bubbly Creek, the construction of an outfall sewer into the West 39th St. conduit and the diversion of the Robey St. sewer into the same conduit. This is estimated to cost approximately $985,000. Several slight modifications are possible. It is assumed that the proposed Center Ave. sewer will discharge directly into the Creek.

This project handles the wastes as separately as possible with the presence of some domestic sewage, and is flexible with regard to the future.

BIOLOGICAL TREATMENT. In order to make the discussion more complete, a brief study has been made of the possibility of treating biologically the industrial wastes from the Stockyards and Packingtown at a point outside of and west of the city limits. This would require the construction of an intercepting sewer westward along the general line of 39th St. or thereabouts to a point in the general region between the city limits and the village of Summit, on a tract of land lying north of Archer Ave. An interceptor for twice the dry weather flow would be approximately 7.5 ft. in diameter, and necessarily would be so far below the ground at the outfall that pumping would be required in order to lift the sewage onto the filter beds and secure sufficient head to discharge into the drainage canal. It is assumed that the screening and sedimentation will be carried out in the Stockyards and Packingtown in accordance with the recommendations previously made herein, and that the sewage thus prepared would be delivered to the works. Roughly speaking, the

approximate cost of the intercepting sewer, pumping station, sprinkling filters, and collateral works including an outfall from the works to the drainage canal would be $3,600,000, entirely exclusive of right-of-way, land, engineering, and legal expenses. These figures are not as carefully prepared as those in the preceding pages, and are given merely to indicate what the ultimate solution will cost. They are also subject to revision, in accordance with the results of a long time test still running on the sprinkling filter, which is planned to continue through another summer season.

APPENDIX I.

LIST OF FIRMS IN THE STOCK YARDS AND PACKINGTOWN. OUTLETS INSPECTED AND TESTED.

1911.

Adler & Oberndorf.
Anglo-American Packing & Provision Co.
 Catch Basin (A).
Armour & Company.
 43rd St. (A)
 43rd Place (B)
 44th St. (C)
H. Bobsin,—Sausage Casings.
H. Boore & Company.
Boyd-Lunham & Company.
Brennen Packing Company.
Chicago Packing Company.
Darling & Company,—Fertilizers,—Glue Factory.
Friedman Mfg. Company,—Butterine.
L. Glick,—Sausage Casings.
Henry Guth.
G. H. Hammond Company.
 Catch Basin (A)
 South Sewer (B)
Hine Bros. Company,—Rendering Works.
Independent Packing Company.
Libby, McNeil & Libby.
Mickelberry Farm Products Company,—Sausages.
Miller & Hart.
Morris & Company.
 Hog Plant.
 42nd St.
 44th St.
 Ammonia Plant.
Northwestern Glue Company,—Glue and Fertilizer.
Peoples Packing Company.
Pfaelzer & Sons.
Roberts & Oake.
Siegel-Hechinger Provision Company.
Standard Slaughtering Company.

Sulzberger & Sons Company.

Grease Sewer through Catch Basin

Red Sewer.

Swift & Company.

40th to Ashland (A)

42nd to Ashland (B)

Packers Ave. (C)

41st to Center (D)

42nd to Center (E)

Wool House (F)

Union Stockyards & Transit Co.

Western Packing Company.

Catch Basin (A)

Wash Water (B)

NOTE:—The letters following the designation denote the individual outlets examined.

APPENDIX II.

Report of Test at Plant of
ADLER & OBERNDORF.
June 22 and 23, 1911.

PLANT. Adler & Oberndorf manufacture inedible tallow and fertilizer, and deal in hides. They gather scraps, bones, etc., from various meat markets, restaurants and small slaughtering houses, and take all the waste, scraps and offal from the slaughtering firm of Peacock and Sheehan, and the casing cleanings and rejected casings from the Western Casing Co. Everything is rendered for inedible grease, and the remaining solids utilized in manufacturing fertilizer. The concern has no evaporator, but claim that their tankage is cooked to a dryness before pressing that leaves practically no tank water, and that the little which reaches the settling basins remains so long that all the grease is skimmed off. The solids from the catch basins are used with the solid tankage for fertilizer filler.

DRAINAGE. There are only two wooden catch basins of any size, the rest being clean-out manholes. The total length of flow in the two is estimated at 75 ft., each basin being 4 ft. wide and 18 in. flow depth, baffled with scum boards and an outlet baffle. The flow is usually small.

PEACOCK & SHEEHAN. Peacock & Sheehan are slaughterers, renting space from Adler & Oberndorff. Their usual kill is 100 to 150 sheep and 30 to 40 calves per day, killing only a few hours each day. During the test the kill was: June 22, 151 sheep, no calves; June 23, no sheep up to 4 p. m., 30 calves.

The sewage is principally blood and wash and floor water, passing direct to the sewer. There is no paunch manure, as the paunches are bought whole by Adler & Oberndorf and rendered for fertilizer.

WESTERN CASING CO. The Western Casing Company rents space of Adler & Oberndorf. They buy green casings from the smaller houses, cleaning and packing them. Their usual run is 3,500 casings a day. The sewage is mostly wash water. There is no catch basin.

SEWER AND WEIR. The sewage from these three firms enters the Center avenue sewer through a 12x12 in. box sewer. A 12-in. weir without end contractions was built in this sewer in a manhole just below Adler & Oberndorf. Readings and samples were taken June 22 and 23 (table 124).

TABLE 124.

CHEMICAL ANALYSES OF OUTFLOW FROM ADLER & OBERNDORF.

June 22 to 23, 1911.

Date June	Period of Collection.	Flow c.f.p.s.	Parts Per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity $CaCO_3$
			Total	Volatile	Fixed	Total	Soluble	Sus-pended	Organic Nitrogen	Free Ammonia	
22	10 a. m. to 4 p. m.	0.13	212	184	28	301	234	67	104	40	240
23	8 a. m. to 4 p. m.	0.14	652	600	52	432	303	129	260	76	316

APPENDIX III.

Report of Test on Plant of
ANGLO-AMERICAN PROVISION CO.
April 25 to 28, 1911.

PLANT. The Anglo-American Provision Co. is a typical packing house, of moderate size, slaughtering hogs and a few cattle, preparing dressed, smoked and canned meat, and producing a few by-products such as oleomargarine, tripe, soap fats, grease and fertilizer.

PAUNCH MANURE. Since the major killing is hog, both digested manure and hog paunch manure are saved. From the cattle killing, the paunch manure is collected, shovelled into a car and shipped out by rail.

BLOOD, RENDERING, ETC. The blood is collected, and dried for fertilizer. All the scraps are rendered, the solid portion being pressed and dried, mixed with stick and sold as tankage. The liquid from the rendering tanks is evaporated and dried.

SEWERAGE SYSTEM. The sewerage of the Anglo-American plant has two main subdivisions, discharging directly into the Chicago River, about 200 feet west of Center Ave. bridge.

I. The cattle killing and power house outlet.

This receives the outflow from the subsidiary catch basin at the outlet of the cattle killing floor, the drain from the oleo plant, and the office toilets, as well as the condensing water from the power plant and fertilizer condensers. As arranged and operated, this is normally by-passed around the large catch basin, emptying into a crude screening box on the edge of Bubbly Creek.

II. The hog killing, and allied branches.

This line receives the drainage from the plant of David Levi, a small slaughtering house, killing cattle for local trade, discharging all floor wash, drainage, etc. From the Anglo-American plant proper is received the waste water from the hog killing floor, the trimming floor, the scald water and the fertilizer department, as well as drainage from the dressing room, the packing floor, smoke house, grease and lard refineries, the toilets in a portion of the plant, and the down-spouts from the roof.

This sewerage system after passing through a concrete catch basin, joins the first division.

PLANT CAPACITY. The plant capacity is rated at 100 cattle

daily, and 1,200 to 2,000 hogs. During the test the following kill was made:

1911	Cattle.	Hogs.
April 25,	100	2,000
26,	80	1,400
27,	100	1,300

MAIN CATCH BASIN. The main catch basin is built of concrete, 106 ft. long by 15 ft. wide, with a normal flow depth of $2\frac{1}{2}$ to 3 ft. It has served to retain the grease for skimming purposes, with small settling effect on the sewage. The outlet end was equipped with three wire screens of $\frac{1}{4}$ in. mesh, previous to the test. Subsequently, on April 29, 1911, three boiler plate screens, 8 ft. wide, were installed, punched full of holes respectively $\frac{1}{4}$, $\frac{1}{8}$, and 1/16 in. diameter. The influent end, baffled to form a grease trap of the first 35 feet, was remodeled on April 25, 1911. Otherwise the tank is baffled alternately top and bottom, the baffles being spaced 8 ft. apart.

CLEANING CATCH BASIN.—SLUDGE. The catch basin was partly cleaned, two days before the test, by by-passing the sewage to the river, and draining down the water in the tank. Some 18 inches of sludge was exposed, black, very heavy and compact, with no very distinct odor. This was shoveled out onto the ground, dried for a day, then carted away to the fertilizer plant.

BEEF HOUSE CATCH BASIN. The catch basin at the beef slaughter house is made of timber, 16 ft. square, with a flow depth of some 3 ft., with a short overflow baffle at the outlet. Grease is skimmed by one man. Screens are provided on the upstream side of the effluent baffle, built of $\frac{1}{4}$ in. boiler plate on edge, about 3 ft. away from the side of the tank. These screens are open at the bottom, and pass grease and floating solids.

RIVER SKIMMING BASIN. Both outlets discharge on the bank of the river into a crude skimming basin, 66 ft. long, 5 ft. 6 in. wide, with a flow depth of approximately 16 in. On the side adjacent to the river is a $\frac{1}{4}$ in. mesh screen, 16 ft. long, open at the bottom or sides which retains floating matter.

WEIRS. The first weir was built at the outlet of the hog catch basin, below the screen, on April 24, 1911, with a crest 24 in. wide and end contractions. After starting the run, the second sewer system was found by-passed direct to the river basin. A second weir was built on the combined sewers, at the inlet end of the river basin.

FLOW. The computed flow for both weirs is given in table 125.

The maximum average total flow for 24 hours, 1.8 cu. ft. per sec., occurred on the 27th. No zero flow was recorded. The combined or total flow was 0.1 to 0.5 cu. ft. per sec. greater than the flow through the catch basin.

FIELD WORK. The duration of the test was 77 hours, samples being collected, and the head on the weirs read and averaged according to the following schedule:

ONE HOUR. Between 8 a. m. and 2 p. m. a portion of about 500 c. c. was collected every 10 minutes and averaged in a gallon bottle for the hour, the weir being read also.

TWO HOURS. Between 2 p. m. and 8 p. m. a portion of about 200 c. c. was collected every 10 minutes and averaged in a gallon bottle for the two hours, the weir being read also.

FOUR HOURS. Between 8 p. m. and 8 a. m. a portion of about 200 c. c. was collected every 15 min. and averaged in a gallon bottle for the 4 hour period, the weir being read also

RESULTS. The suspended matter (Table 125) is lower than in the preliminary test of one hour, possibly due to lighter killing, the partial cleaning of the settling basin and the greater pumpage of condenser water. However the suspended matter in the outlet of the catch basin (Weir A) ran up to 472 parts per million, over three times that of the normal city sewage. The combined flow, measured by weir B, including the condenser water of the power plant and evaporators, is more dilute, the highest suspended matter being 240 parts per million. Chunks and shreds of offal, and other waste, however, show in the combined outlet, which the usual method of sampling does not include.

TABLE 125.

CHEMICAL ANALYSES OF OUTFLOW FROM ANGLO-AMERICAN PROVISION CO.

April 25 to 28, 1911.

Description.	Flow in c. f. p. s.	Parts per Million.					
		Suspended Matter.			Oxygen Consumed.		
		Total.	Volatile.	Fixed.	Total.	Volatile.	Fixed.
		SEWER A.					
Maximum......	2.00	484	432	52	500	366	134
Minimum......	0.82	104	...	...	102	51	51
Average........	1.43	262	212	50	183	132	51
		SEWER B.					
Maximum......	2.61	280	...	...	125	85	40
Minimum......	1.05	98	...	...	48	33	5
Average........	1.70	154	123	31	85	62	23

COLOR TEST. To determine the period of flow through the catch basin a color test was made on April 28, at 4:30 p. m. The color appeared at the outlet end in 17 minutes and was very noticeable in the river basin after 19 minutes.

PERIOD IN TANK. The calculated period in the catch basin may be obtained from the flow over the catch basin weir.

TABLE 126.

NOMINAL ELEMENTS OF CATCH BASIN.

Flow, c. f. p. s.	Period in Catch Basin, Min.	Av. Velocity, Ft. per Min.	Max. Velocity, Ft. per Min.
0.25	318	0.33	1.0
0.50	159	0.66	2.0
0.75	106	1.0	3.0
1.00	79½	1.3	4.0
1.25	63	1.6	5.0
1.50	53	2.0	6.0
2.00	40	2.6	8.0

The maximum velocity is calculated using the space below a scum board as the flow area, the lower edge of the baffle being 12 in. above the floor.

COMPARISON OF INFLUENT AND EFFLUENT. In order to determine the efficiency of the catch basin, average samples were collected at the influent end, corresponding to those collected at the effluent end for the same time. This shows very variable results (table 127).

TABLE 127.

COMPARISON OF INFLUENT AND EFFLUENT.

Date April	Time.	Flow, c.f.p.s.	Period in C. B., Min.	Total Suspended Matter P. P. M.		Percent. Reduction.
				Influent.	Effluent.	
25	11 a.m. to 12 M.	0.84	95	704	360	49
25	8 p.m. to 12 Mdt.	1.61	50	160	178	Increase
26	11 a.m. to 12 M.	1.95	41	518	424	18
26	8 p.m. to 12 Mdt.	0.80	99	184	166	10
27	10 a.m. to 11 a.m.	1.78	45	460	272	41
27	11 a.m. to 12 M.	1.93	41	310	296	5
27	8 p.m. to 12 Mdt.	0.82	97	228	204	11

SLUDGE. A sample of sludge was collected April 24, while the basin was being cleaned. This was black and decomposed, seemingly composed of sand, cinders and paunch manure, with a strong putrid odor. The specific gravity was 1.23.

SLUDGE ANALYSIS.

Determination—	Per Cent.
On Sample, moisture	58
On dry basis, volatile matter	25
fixed matter	75
nitrogen	1.04
fat	1.33

SETTLING EXPERIMENTS. Experiments on the settling of the effluent in a 300 c. c. cylinder show that from 27 to 46 per cent. of suspended matter in the effluent of the present catch basin will settle out in 1 hour under quiescent conditions, and that 42 per cent. of the suspended matter in the final effluent will settle out in 1 hour under quiescent conditions.

APPENDIX IV.

Report of Tests Made at Plant of
ARMOUR AND CO.
May 23 to 26, 1911.

LOCATION. The Armour plant is located at 43d street and Center avenue, extending south as far as 45th street, and west to Loomis street. The soap and glue departments are at 31st and Benson streets.

PLANT. Armour and Company have a packing house of the largest type. Hogs, cattle, calves and sheep are killed. Dressed, smoked and canned meats are prepared, as well as oleomargarine, tripe, sausage, lard, soap, glue, inedible grease and fertilizer. A hair factory and wool pullery are also maintained.

CAPACITY. The nominal daily capacity was not given, but the average normal kill, based on the kill for 1910, is as follows:

Cattle	1,100
Calves	365
Sheep	4,000
Hogs	3,500

The actual capacity may possibly be estimated 25 per cent. greater.

SLAUGHTERING. The actual kill, during the test, was not given out, but the number was said to be about an average.

OPERATION. The various operations are practically identical with those of the other larger houses. The blood is collected, coagulated and filtered, and used for fertilizer. All scraps, offal, etc., are rendered for inedible grease, along with the grease skimmed from the skimming vats. The tankage is pressed and dried for fertilizer, and all tank liquors are evaporated.

MANURE. All pen and paunch manure is loaded into cars and shipped to the country for fertilizer. Settling tanks are provided for the overflow from the paunch manure presses, but part escapes into the sewers.

This was especially evident in the 43d place sewage. In the catch basin there, the sewage is largely composed of paunch manure.

SEWERS. The sewers of the Armour plant are divided into three systems, all emptying into the Center avenue sewer. These are on 43d street, 43d place and 44th street, and are interconnected

at several points to divert a part of the flow from any one system to another. The arrangement at the time of the test was normal.

43d STREET.

DESCRIPTION. This is a new circular, brick sewer, 36 in. diameter at the outfall. It joins the Center avenue sewer just north of the general office building. Draining into it are the cattle, hog and sheep killing floors, engine and boiler rooms, refrigerator plant, drains from cold storage and warehouses, sausage cooking rooms, pickled meat, tripe and casing cleaning departments, besides numerous toilets and down spouts along 43 street.

CATCH BASINS. Seven catch basins and grease tanks are located along this line. Through none does the entire flow pass. The largest is on Center avenue, just north of 43d street. This receives the flow from several cooking rooms, and the tripe and pigs feet rooms. It is built of concrete 40 ft. long by 8 ft. wide, with a normal flow depth of 3½ ft. There are underflow baffles 8 ft. apart, extending down to a point 6 in. above the floor.

No samples were taken from this basin. The flow seemed fresh. There was very little deposit on the bottom.

WEIR AND SAMPLES. A weir was built in a manhole at 43d street, and Center avenue, receiving all the flow except that from the general office building, toilets, kitchen wastes, and water from the heating plant. The weir was 2.5 ft. long, with end contractions, the crest being 16 in. above the invert of the manhole. Readings were taken with a hook-gage suspended in the manhole, 2 ft. back from the crest. To build the weir a ladder was lowered into the manhole. Whenever this ladder was raised, the lower rungs were covered with casings. These had to be cleaned off before the ladder could be lifted out. Chunks of meat and skin were noticed, which were not considered in the analyses.

Readings and sampling started at 2 p. m., May 23d, and continued for 72 hours, composite samples being taken over periods of two hours during the day, from 8 a. m. to 4 p. m., a portion being taken every 20 minutes. From 4 p. m. to 8 a. m. the composites covered a period of four hours, small portions being taken every 20 minutes.

ANALYSIS. The results of analyses of the samples are shown in table 128.

SETTLING EXPERIMENTS. Experiments on settling the effluent in a 500 c. c. cylinder show that about 46 per cent. of the total suspended matter will settle out in one hour under quiescent conditions.

TABLE 128.

CHEMICAL ANALYSES OF FLOW OF 43RD ST. SEWER. ARMOUR & COMPANY.

May 23–26, 1911.

May	Period of Collection.	Flow c. f. p. s.	Parts Per Million.					
			Suspended Matter.			Oxygen Consumed.		
			Total	Volatile	Fixed	Total	Soluble	Suspend.
23	2 to 4 p. m.	3.0	1188	1040	148	588	445	143
	4 to 8 p. m.	2.7	688	592	96	360	230	130
	8 to 12 Mid.	0.3	184	...	...	...	...	...
24	12 to 4 a. m.	0.5	126	...	...	...	...	...
	4 to 8 a. m.	0.7	180	...	...	...	...	...
	8 to 10 a. m.	2.7	600	...	...	...	...	...
	10 to 12 M.	3.1	892	792	100	448	331	117
	12 to 2 p. m.	2.8	532	...	...	...	...	...
	2 to 4 p. m.	3.4	656	...	...	...	...	...
	4 to 8 p. m.	3.2	644	560	84	...	...	...
	8 to 12 Mid.	1.3	170	...	...	...	...	...
25	12 to 4 a. m.	1.2	122	...	...	...	...	...
	4 to 8 a. m.	2.0	140	...	...	...	...	...
	8 to 10 a. m.	3.4	640	...	...	...	...	...
	10 to 12 M.	3.6	404	224	180	334	209	125
	12 to 2 p. m.	2.7	540	...	...	...	...	...
	2 to 4 p. m.	3.5	...	...	...	...	...	...
	4 to 8 p. m.	2.7	728	...	...	...	...	...
	8 to 12 Mid.	0.8	308	...	...	...	...	...
26	12 to 4 a. m.	1.2	74	...	...	...	...	...
	4 to 8 a. m.	1.4	182	...	...	...	...	...
	8 to 10 a. m.	2.3	500	...	...	...	...	...
	10 to 12 M.	3.4	680	...	...	...	...	...
	12 to 2 p. m.	2.1	404	332	72	282	201	81

43d PLACE SEWER.

DESCRIPTION. This is an 18 in. main, discharging into a catch basin, which empties through a 24 in. tile sewer into the Center avenue sewer. It drains chiefly the pork dressing and canning rooms, lard refinery, oleo and butterine house, smoke house and main sausage house. A portion of the power-house water, and the down spouts along 43d place also enter.

CATCH BASIN. All the flow passes through a timber catch basin on Center avenue, 104 ft. 6 in. long, by 6 ft. 2 in. wide, with a flow depth of 24 in. under ordinary conditions. The basin is divided longitudinally by a timber baffle, making the total length of flow about 200 ft. Only under flow baffles or scum boards are provided, extending down to a point 15 in. above the floor. The deposit is usually so deep, however, that the actual flow space under the baffles is much less. There are three wire screens, of ½ in. mesh, at the outlet end, which are cleaned several times daily, by lifting and shaking off the clogging material.

Two, and sometimes three, men are kept at the basin, cleaning out the sludge and skimming off the grease. This is carted away, the sludge being pressed and used for fertilizer, the grease being rendered.

WEIR. A 2 ft. weir, with two end contractions, was built across the outlet end of the basin. Ordinarily a 3 in. hole through the central baffle connects the inlet and outlet ends of the basin, by-passing a part of the entering sewage. During the test this hole was plugged.

READINGS AND SAMPLES. Sampling was begun at 2 p. m., May 23, 1911, and continued in the same way as at 43d street.

SETTLING EXPERIMENTS. Settling experiments on the

TABLE 130.

NOMINAL ELEMENTS OF 43RD PL. CATCH BASIN.

Flow, c. f. p. s.	Period, Min.	Av. Velocity, Ft. per Min.
1.0	21	9.5
1.5	14	14.3
2.0	10.5	19.1
2.5	8.4	24
3.0	7.	29

effluent of the catch basin show that from 50 to 60 per cent. of the suspended solids will settle out in one hour under quiescent conditions.

TABLE 129.

CHEMICAL ANALYSES OF OUTFLOW OF 43RD PLACE CATCH BASIN. ARMOUR & COMPANY.

May 23 to 26, 1911.

May	Period of Collection.	Flow c. f. p. s.	Parts Per Million.					
			Suspended Matter.			Oxygen Consumed.		
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspended.
23	2 to 4 p. m.	2.6	744	...	...	240	128	112
	4 to 8 p. m.	2.9	708	596	112	275	171	104
	8 to 12 Mid.	1.6	202	...	...	...	...	...
24	12 to 4 a. m.	1.4	88	...	...	...	...	...
	4 to 8 a. m.	1.0	468	442	26	...	...	...
	8 to 10 a. m.	2.0	1124	984	130	...	...	...
	10 to 12 M.	2.4	1064	...	...	...	...	...
	12 to 2 p. m.	2.6	596	...	...	...	...	...
	2 to 4 p. m.	3.2	612	...	...	...	...	...
	4 to 8 p. m.	2.6	976	796	180	422	276	146
	8 to 12 Mid.	1.9	1056	...	...	...	...	...
25	12 to 4 a. m.	1.9	1038	...	...	...	...	...
	4 to 8 a. m.	1.9	420	...	...	...	...	...
	8 to 10 a. m.	2.1	888	...	...	...	...	...
	10 to 12 M.	2.2	1020	912	108	684	581	103
	12 to 2 p. m.	2.2	620	...	...	...	...	...
	2 to 4 p. m.	2.8	736	...	...	...	...	...
	4 to 8 p. m.	2.5	1924	...	...	...	...	...
	8 to 12 Mid.	1.7	180	...	...	...	...	...
26	12 to 4 a. m.	1.8	146	...	...	...	...	...
	4 to 8 a. m.	1.6	444	...	...	...	...	...
	8 to 10 a. m.	1.9	896	...	...	...	...	...
	10 to 12 M.	2.1	1024	...	...	...	...	...
	12 to 2 p. m.	2.0	616	572	44	382	286	96

FLOW. The calculated flow of the 43d place sewer and the chemical analyses are shown in table 129.

SLUDGE. Although sludge is continually removed from the basin, from 6 in. to a foot may always be found on the bottom, deepest at the influent end. This is composed of cinders, scraps of flesh, hides and offal, and paunch manure, and is fairly fresh, with a strong "pig-pen" odor.

SLUDGE ANALYSIS.

	Per Cent.	
Moisture	58	
Volatile matter	26	on dry basis
Fixed "	74	"
Nitrogen	1.4	"
Fat	1.7	"

PERIOD IN CATCH BASIN. The nominal period in the catch basin may be estimated from the flow of the effluent weir (table 130).

44th STREET SEWER.

DESCRIPTION. The 44th street sewer is a 24 in. tile sewer, receiving the drainage from the stables, fertilizer factory, wool pullery, part of the oleo house, and from the cooper shop and lumber yard.

CATCH BASIN. No catch basin is provided on the main line, but the water from the wool pullery passes through two, both built of timber. One receives the flow from the wool cleaning vats, and the other the flow from the liming vats. The first is 47 ft. long, by 4 ft. 6 in. wide, with a flow depth of about 4 ft. There are underflow baffles, extending to a point 24 in. above the bottom of the tank. The second is similar, except that it is 56 ft. 6 in. long. These basins are kept clean. The sludge from the first is composed largely of manure and dirt washed from the pelts. Brown in color, with a gaseous odor, it is used for fertilizer. The sludge from the second is largely slaked lime and wool. Dirty white in color, it has a characteristic lime odor. The wool in it is recovered.

WEIR. A weir 2.0 ft. long with end contractions was built in a timber manhole at Center avenue. Readings were taken with a hook gage.

READINGS AND SAMPLES. Readings and samples were started May 23d, but owing to a leak in the weir, the readings prior to 2 p. m., May 24th, were discarded (table 131).

TABLE 131.

CHEMICAL ANALYSES OF FLOW OF 44TH ST. SEWER. ARMOUR & COMPANY.

May 23 to 26, 1911.

May	Period of Collection.	Flow c. f. p. s.	Parts Per Million.					
			Suspended Matter.			Oxygen Consumed.		
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspended.
23	2 to 4 p. m.	...	1560	856	704	395	269	126
	4 to 8 p. m.	...	1580	896	684	563	399	164
	8 to 12 Mid.	...	442	...	...	...	...	...
24	12 to 4 a. m.	...	1340	...	...	...	...	...
	4 to 8 a. m.	...	2186	1834	352	255	178	77
	8 to 10 a. m.	...	2760	1692	1078	...	...	...
	10 to 12 M.	...	1240	...	...	...	...	...
	12 to 2 a. m.	...	1468	...	...	...	...	...
	2 to 4 a. m.	1.5	1148	...	...	...	...	...
	4 to 8 a. m.	1.2	896	...	...	...	...	...
	8 to 12 Mid.	0.05	170	...	...	...	...	...
25	12 to 4 a. m.	0.28	158	...	...	...	...	...
	4 to 8 a. m.	0.31	400	...	...	...	...	...
	8 to 10 a. m.	1.5	1088	...	...	...	...	...
	10 to 12 M.	1.7	1364	...	...	...	...	...
	12 to 2 p. m.	1.6	1768	836	932	521	375	146
	2 to 4 p. m.	1.7	1432	...	...	...	...	...
	4 to 8 p. m.	1.4	744	...	...	...	...	...
	8 to 12 Mid.	0.12	128	...	...	...	...	...
26	12 to 4 a. m.	0.05	58	...	...	...	...	...
	4 to 8 a. m.	0.64	....	...	...	...	...	...
	8 to 10 a. m.	1.8	1280	628	662	412	266	146
	10 to 12 M.	1.7	1164	...	...	...	...	...
	12 to 2 p. m.	1.6	872	412	460	419	350	69

APPENDIX V.

ARMOUR GLUE WORKS.

Tests were made in October, 1910, at the Armour Glue Works, near 31st and Benson streets, to determine the character of the wastes discharging into the river. The factory manufactures glue, bone dust, fertilizers and soap. In the washing of the pieces of hides, hair and other refuse from the tanneries, a deal of lime is set free, which the superintendent, Mr. Kiley, estimates at one ton a day. All this goes into the river. The water consumption is estimated at about two million gallons a day for all purposes. This includes the water from the vacuum pans where the glue is concentrated, the condenser water, and all wash water from the plant. There are at present some so-called catch basins in the basement of one building. These are designed and operated as grease traps, and do not hold back any of the lime sediment, and cannot be classed as settling basins. At present no effort is made to hold back any of the suspended matter, other than grease, except through the use of punched copper screens on the washing tanks, which retain some hair.

There are nine outlets, eight of which were sampled, numbered from 0 to 7. It is probable that the waste discharged from the outlet not sampled is similar to that of No. 7. Sampling began at 11:30 A. M. Monday, Oct. 24, 1910, a portion being taken every half hour from each of the outlets, running for 24 hours consecutively. These tests were extended over the 24, 25 and 26 of October, and ended at 8:00 A. M., October 27 (table 132).

The character of the waste was indicated by the chemical analyses shown on table 132. Observations also showed a difference in the character of the discharge of the outlets, as No. 0 and No. 1 apparently receive very slight amounts of industrial wastes. This was checked by the analyses. The other outlets showed signs of gross pollution, particularly as indicated by the suspended matter. This is excessively high on outlets Nos. 3, 4, 5, 6 and 7. In No. 4 and No. 7 it is high practically all the time, and on the others particularly in the daylight hours, running light at night when a portion of the works is shut down. The suspended matter on an average for 24 hours ran as high as 2,444 parts per million, on No. 4, of which 1,444 parts were volatile and 1,000 fixed matter. Much of this is calcium carbonate and hydrate, largely slaked lime from the washing vats. The organic matter is high throughout. In ex-

TABLE 132.

CHEMICAL ANALYSES OF WASTES FROM GLUE WORKS OF ARMOUR & CO.

October 24 to 26, 1910.

Sewer Outlet	Time	Parts per Million													
		Nitrogen as		Oxygen Consumed	Chlorine	Suspended Matter			Alkalinity as $CaCO_3$					Fats
		Organic	Free Amm.			Total	Volatile	Fixed	Methyl Orange	Phenolphthalein	Bicarbonates	Carbonates	Hydrates	
0	8 a.m. to 8 a.m.	17	5.7	46	82	86	60	26	167	0	167	0	0	..
1	8 a.m. to 8 a.m.	17	6.1	46	81	97	80	17	165	0	165	0	0	..
2	8 a.m. to 8 a.m.	17	5.8	51	86	153	107	46	173	0	173	0	0	..
3	8 a.m. to 8 p.m.	130	13	173	96	718	613	105	204	22	160	44	0	..
	8 p.m. to 8 a.m.	18	13	56	91	71	48	23	191	0	191	0	0	..
4	8 a.m. to 8 a.m.	96	40	251	254	1603	1020	583	544	113	318	226	0	..
5	8 a.m. to 8 p.m.	134	21	141	124	686	241	445	1505	1081	80	682	743	..
	8 p.m. to 8 a.m.	22	7.7	61	71	245	118	127	228	31	166	62	0	..
6	8 a.m. to 8 p.m.	252	23	239	311	1179	732	447	287	52	185	101	1	..
	8 p.m. to 8 a.m.	136	12	150	202	311	219	92	118	0	118	0	0	..
7	8 a.m. to 8 a.m.	118	12	183	207	1642	903	739	1490	1096	0	785	705	65

periments under quiescent conditions, the major portion of the suspended matter settled out in 30 minutes, and in all cases two hours sufficed. On samples from No. 4 and No. 7 a scum formed, showing that some of the suspended matter is very light and greasy, probably the volatile portion.

From the analyses, the waste waters from three outlets appear of reasonable quality, as they are not much stronger than average sewage. The other outlets contain at times so much suspended matter that they should be collected in a common basin for settling, with a settling period of at least two hours. Scum boards are required to hold back the grease or floating suspended matter. The basin should have hopper bottoms to facilitate cleaning.

APPENDIX VI.

Report of Test at Plant of
BOYD-LUNHAM COMPANY.
June 20 and 21, 1911.

LOCATION. The Boyd-Lunham plant is at 45th and Cook streets, west of Roberts and Oake. Their sewage outlet is to Center avenue by way of 45th street.

PLANT. This is one of the smaller packing houses, doing only a pork business. Dressed, smoked and boiled, and pickled meats are prepared, but no canning is done. Lard, grease and fertilizer are made. Two hundred and fifty to three hundred men are employed.

CAPACITY. The capacity of the plant was given as 250,000 hogs per annum. The kill during the two days of the test was 1,480 and 443 hogs, respectively. The kill usually begins at about 8 a. m., lasting until 4 or 5 p. m. The plant is not operated at night so that the cleaning up practically terminates the flow of sewage.

OPERATION. Most of the blood is saved, coagulated and filtered, and added to the fertilizer. All wash and floor water goes to the catch basin. Offal and scraps are rendered for grease, the tank liquid is evaporated for "stick," and the solid tankage pressed and dried for fertilizer filler. All paunch manure is put into the rendering tanks, without being pressed. No ground bone is made, but steam bone is utilized with the tankage. All hair is sold green.

SEWERS. The flow from the killing floor, cutting rooms, tank rooms, sausage and fertilizer departments, and the smoke house, passes through the catch basin. Toilets, down spouts, condenser water, etc., drain direct to the street sewer.

CATCH BASIN. The catch basin is of timber 21 ft. long by 3 ft. wide, with a minimum flow depth of 2 ft. 7 in. There are four sets of under- and over-flow baffles, the baffles of each set being 12 inches apart. The under-flow baffles are 12 in. above the bottom of the basin, while the over-flow baffles are 5 to 7 in. below the surface. At the effluent end, the water passes over a tight baffle, 2 ft. 7 in. high, and through two ¼ in. mesh wire screens.

The basin is said to be cleaned once a week, the sludge being used for tankage. No regular care is taken of the basin, the screens being cleaned only when badly clogged.

MEASUREMENTS AND SAMPLES. As no plant discharges

TABLE 133.

CHEMICAL ANALYSES OF CATCH BASIN EFFLUENT. BOYD-LUNHAM CO.

June 20 and 21, 1911.

June	Flow c. f. p. s.	Period of Collection.	Analysis in Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspend.	Organic Nitrogen.	Free Ammonia.	
20	0.82	10 a.m. to 4 p.m.	648	536	112	264	200	64	82	30	350
21	0.55	8 a.m. to 4 p.m.	660	524	136	419	320	99	197	40	290

into the 45th street sewer above Boyd-Lunham, a weir was built in a street manhole below their last outlet, and readings and samples taken there. The weir was 1.25 ft. long, without end contractions. Samples were taken from 10 a. m. to 4 p. m., June 20th, and from 8 a. m. to 5 p. m., June 21st. The maximum flow was 0.90, the minimum 0.39 cu. ft. per sec. (table 133).

TABLE 134.

NOMINAL ELEMENTS OF CATCH BASIN.

Capacity 168 Cu. Ft.

Flow, c. f. p. s.	Period in Basin, Min.	Av. Velocity, Ft. per Min.	Max. Velocity, Ft. per Min.
0.25	11.2	1.9	5.0
0.50	5.6	3.8	10.0
0.75	3.7	5.6	15.0

SETTLING EXPERIMENTS. Settling experiments with the outflow of the Boyd-Lunham plant show that 50 to 60 per cent. of the total suspended solids will settle out in one hour under quiescent conditions.

APPENDIX VII.

Report of Test at Plant of BRENNAN PACKING COMPANY. July 11 and 12, 1911.

PLANT. This is a moderate sized concern, located at 3916 Butler street, conducting a fresh and pickled pork business. The usual daily kill is about 750 hogs. There is no smoke house, tripe room, bone room or hide cellar, although several sweet pickle rooms drain out considerable brine. No fertilizer is made, but the scraps, etc. go to a tank house, the solid tankage being sold for fertilizer filler, to which the paunch manure is added. The tank water is not evaporated, but goes to the catch-basin.

CATCH BASIN. The catch-basin is concrete, 41 ft. long by 4½ ft. wide, with a normal flow depth of 18 in., or less. It is baffled alternately with over- and under-flow baffles 4 ft. on centers. The under-flow baffles have a bottom clearance of about 4 in., while the over-flow baffles are nominally about 3 in. under the surface. With the weir in there was about 5 in. of water over them. Two feet from the outlet end is a timber underflow baffle. The flow is taken from the down-stream side of this, at the surface, by a vertical 8 in. tile which passes out through the floor. Above the catch-basin proper, several grease tanks are located, 4 ft. by 6 ft., and about 18 in. deep. Three of these were in use at the time of the test. The catch-basin receives the entire flow except from one sweet pickle cellar. A weir 2 ft. wide, with end contractions, was built across the basin about 6 ft. back from the outlet end. The crest of the weir was 18 in. above the floor. Readings and samples were taken for two days, from 8 a. m. to 4 p. m. only. The maximum flow was 0.50, the minimum 0.29 cu. ft. per sec. (table 136).

TABLE 135.

NOMINAL ELEMENTS OF CATCH-BASIN.

Capacity is 271 cu. ft.

Flow c. f. p. s.	Period in Basin, Min.	Av. Velocity Ft. per Min.	Max. Velocity, Ft. per Min.
0.20	23	1.8	8.0
0.30	15.4	2.7	12.0
0.50	9.2	4.4	20.0

TABLE 136.

CHEMICAL ANALYSES OUTFLOW OF CATCH BASIN, BRENNAN PACKING CO.
July 11 to 12, 1911.

Date July	Period of Collection.	Flow c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspend.	Organic Nitrogen.	Free Ammonia.	
11	10 a.m. to 4 p.m.	0.46	1732	1312	420	731	349	382	698	62	540
12	8 a.m. to 4 p.m.	0.39	1084	916	168	567	476	91	450	54	440

SETTLING EXPERIMENTS. Settling experiments with the effluent of the catch-basin show that 60 to 70 per cent. of the total suspended solids will settle out under quiescent conditions.

APPENDIX VIII.

Report of Tests at Plant of
CHICAGO PACKING COMPANY.
June 20 and 21, 1911.

PLANT. The plant of the Chicago Packing Company is located at 4531 Gross avenue. A general slaughtering and packing business is conducted on a small scale, slaughtering cattle, calves and hogs, and sheep subsequent to June 1, 1911. The products are dressed, smoked and boiled meats, tripe, lard and inedible grease. About fifty men are employed.

CAPACITY. The average kill was given as follows:

Cattle......................	50 daily
Calves	60 daily
Sheep......................	100 per week
Hogs	150 per week

MANURE. The pen manure is swept up and dumped at Armour's, whence it is shipped to the country. All paunch manure, except that from calves, is disposed of likewise. There are no paunch manure separators or presses, but the paunches are ripped open and their contents dumped through a chute into carts. In this way very little escapes. The calf paunches are put whole into the rendering tanks for fertilizer.

BLOOD AND RENDERING. The blood is collected, cooked, but not filtered, and then sold to the fertilizer manufacturers. Lard is rendered, and all scraps and offal, along with the calf paunches, are rendered for inedible grease. The liquid goes to the catch-basin, and the solid portion is pressed and sold as tankage. As in other small houses which have no evaporators, the tankage is cooked until practically dry. All casings are cleaned and packed. There is a smoke house, tripe room and a hide cellar. All bones are sold green.

TABLE 137.

NOMINAL ELEMENTS OF CATCH BASIN.

Capacity, 320 Cu. Ft.

Flow. c. f. p. s.	Period in Basin, Min.	Average Velocity, Ft. per Min.	Maximum Velocity, Ft. per Min.
0.10	53.3	0.6	1.5
0.20	26.6	1.2	3.3
0.30	17.8	1.8	4.5

TABLE 138.

CHEMICAL ANALYSIS OF OUTFLOW OF CATCH BASIN, CHICAGO PACKING COMPANY.

June 21 to 22, 1911.

June	Period of Collection.	Flow c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity in $CaCO_3$
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspend.	Organic Nitrogen.	Free Ammonia.	
21	10 a.m. to 8 p.m.	0.22	500	420	80	329	255	74	140	110	500
22	8 a.m. to 6 p.m.	0.22	1756	1660	96	651	475	176	437	107	560

SEWERS AND CATCH BASIN. All sewage, except overflow from pumps, condensing water and toilets, flows through a concrete catch-basin 32 ft. long, 4 ft. wide and about $2\frac{1}{2}$ ft. deep (water depth). The basin is divided into 3 compartments by concrete under-flow baffles, 8 ft. on centers. The flow space below these is 12 in. deep. Between these are timber over-flow baffles, each provided with a 12 in. lift gate. At the outlet are two $\frac{1}{4}$ in. mesh wire screens, which are taken out, singly, when clogged, and cleaned with a steam jet. The screens are said to have been installed about May 1, 1911.

WEIR. A weir was built on the last overflow baffle, just above the screens, with a net length of 3 ft. $\frac{5}{8}$ in. with 2 end contractions. The maximum flow was 0.27, the minimum 0.19 cu. ft. per sec.

APPENDIX IX.

Report of Test at Glue Plant of DARLING FERTILIZER COMPANY. June 13 to 15, 1911.

DESCRIPTION. The Glue Plant of the Darling Fertilizer Company is on 42d street, one block east of Ashland avenue. Glue, inedible tallow and poultry food are made. Selected bones are dried and sold to the button manufacturers.

OPERATION. Bones and fresh meat scraps, bought from markets and restaurants, are collected by the company. As unloaded they are sorted by hand into different grades, the bones being kept separate, and resorted. The thighs or buttocks, leg-bones and ribs, in good condition are saved for the button manufacturers, while rejects are used as "steam" or "soft" bone for making glue.

The scraps of hide, sinew, hoofs or tails are used for making glue, while the meat and fat scraps are rendered for grease. The solid tankage is pressed and dried, then ground for poultry food. The liquid is evaporated. The wash- and floor-water is collected and settled under heat inside the building before going to the catch-basin, to extract the grease.

CATCH-BASIN. The concrete catch-basin is divided into two sections, both located in the alley between the two main buildings. Each is 3 ft. wide by 2½ ft. deep, with a total length of 120 ft. Over- and under-flow baffles are provided, spaced about 8 ft. apart. The under-flow baffles act only as scum boards, but the over-flow baffles extend to about 3 in. below the top of the water. The sewage enters the catch-basin at several points along its length. The effluent discharges through a 20 in. tile emptying into the effluent end of the disused catch-basin on Swift's 42d street line.

A 24 in. weir, with two end contractions, was built in the last overflow baffle. Samples and readings (table 139) were taken during the day only, for two days. The maximum flow was 0.31, the minimum 0.18 cu. ft. per sec.

TABLE 139.

CHEMICAL ANALYSIS OF THE OUTFLOW FROM THE DARLING GLUE PLANT.

June, 1911.

			Parts per Million.								
June	Period of Collection.	Flow c.f.p.s.	Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity in $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspend.	Organic Nitrogen.	Free Ammonia.	
13	12 a.m. to 4 p.m.	0.20	398	354	44	339	259	80	164	44	300
14	8 a.m. to 4 p.m.	0.25	1252	1104	148	448	289	159	326	58	290
15	8 a.m. to 12 M.	0.24	968	876	92	968	876	92	361	61	360

SETTLING EXPERIMENTS. Settling experiments with the effluent of the glue plant show that 70 to 75 per cent. of the total suspended solids will settle out in 1 hour under quiescent conditions.

APPENDIX X.

Report of Tests at Plant of FRIEDMAN MFG. CO. July 6 and 7, 1911.

DESCRIPTION. The Friedman Mfg. Co. is located just west of the Anglo-American plant. Neutral lard, butterine and renovated butter are the products. Only fresh selected stock is used, to avoid waste. No soap is made. The flocculent precipitates present in the samples may be due to the sal-soda used in washing up.

CATCH BASIN AND SEWER. All the flow from the plant passes into a timber catch basin, 24 ft. long by 8 ft. wide, baffled. The flow space under the underflow baffle is 4 in. At the time of the test the depth of water was 21 in., making about an inch over the overflow baffles. At the outlet are three ¼ in. mesh wire screens, all removable. The velocities are all high (table 140).

The outlet sewer empties into the river just south of the line fence of the Chicago Reduction Company, through a small trap, 2 ft. wide by 4 ft. long, which retains a little floating grease, but has no settling value. A weir 1.23 ft. long without end contractions was built across the end of the outlet. Samples and readings (table 141) were taken for two days from 10 a. m. to 4 p. m., and from 8 a. m. to 4 p. m. The maximum flow was 0.17, the minimum 0.11 cu. ft. per sec.

Besides the Friedman Mfg. Co., the toilets of the Chicago Mechanical Mfg. Co., and the Anglo-American stables drain into this sewer below the catch-basin. Both places employ about 85 men. The Friedman Mfg. Co. has a regular force of about 200.

TABLE 140.

NOMINAL ELEMENTS OF FRIEDMAN CATCH BASIN.

Capacity, 336 Cu. Ft.

Flow, c. f. p. s.	Period in Basin, Min.	Av. Velocity, Ft. per Min.	Max. Velocity, Ft. per Min.
0.10	56	0.86	4.5
0.20	28	1.7	9.0
0.30	18.7	2.6	13.5

TABLE 141.

CHEMICAL ANALYSIS OF OUTFLOW OF FRIEDMAN MFG. CO.

July 6 to 7, 1911.

PARTS PER MILLION.

July	Period of Collection.	Average Flow c. f. p. s.	Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.	Fats.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspend.	Organic Nitrogen.	Free Ammonia.		
6	10 a.m. to 4 p.m.	0.14	2372	2260	112	997	893	104	591	29	350	645
7	8 a.m. to 4 p.m.	0.12	2268	2152	116	1180	1078	102	404	21	360	329

SETTLING EXPERIMENTS. Settling experiments with the effluent in a 500 c. c. cylinder show that 28 per cent. of the total suspended solids settle out in 1 hour under quiescent conditions.

APPENDIX XI.

Report of Tests at Plant of
HENRY GUTH.
July 14 and 18, 1911.

PLANT. This house slaughters cattle and sheep on a very small scale, and is located on Halsted street just south of 39th street. The usual kill is about 20 cattle, 15 to 20 calves, and 30 to 40 sheep per day. Everything is done by hand with few modern appliances. Very little water is used, as the carcasses are simply washed off with a sponge or cloth, as dressed. No blood is saved, but all scraps, paunches, etc., are sold. No by-products are made.

FIELD WORK. There is a very small catch-basin. The samples were taken in a manhole. It was not practicable to build a weir, so readings were taken of the water-meter. As there is no evaporation or tank room these readings give a very close line on the sewage flow. Samples and meter-readings (table 142) were taken at 20 minute intervals from 10 a. m. to 4 p. m., July 14th, and from 10 a. m. to 6 p. m., July 18th.

TABLE 142.

CHEMICAL ANALYSIS OF OUTFLOW FROM GUTH SLAUGHTERING HOUSE

July 14 and 18, 1911.

July	Period of Collection.	Flow c.f.p.s.	Parts per Million.							
			Suspended Matter.			Oxygen Consumed.			Nitrogen as	
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspend.	Organic Nitrogen.	Free Ammonia.
14	10 a.m. to 4 p.m.	0.07	1372	1292	80	723	589	134	843	197
18	10 a.m. to 6 p.m.	0.02	4284	4200	84	1092	604	488	632	224

SETTLING EXPERIMENTS. Settling experiments with the effluent of the Guth plant show that 32 to 70 per cent. of the total suspended solids will settle out in 1 hour under quiescent conditions.

APPENDIX XII.

Report of Tests on Plant of
G. H. HAMMOND CO.
April 19 to 22, 1911.

PLANT. The G. H. Hammond Co. plant is a typical packing house, slaughtering cattle, sheep and hogs, preparing dressed, smoked and canned meat, and producing a variety of by-products, such as butter, oleomargarine, tripe, soap fats, grease and fertilizer.

SLAUGHTERING. In the first stages of the packing house, cattle and sheep are killed, cleaned and skinned. The hog is killed and cleaned and the hair removed. Whatever digested manure may accrue is saved and sold, whether from hogs, sheep or cattle. The paunch manure contains, however, semi-digested grain and hay. From the hogs, the solid portion of the paunch manure is used in fertilizer. From the cattle and sheep, the paunch manure is collected into a screw press (or expeller) and compressed to reduce the content of moisture. The dried product can be burned. About 22 lbs. per head of cattle is collected, said to have a fuel equivalent per ton of $\frac{1}{3}$ ton of coal. The liquid waste and water from the floors contains some paunch manure. This passes into the sewer.

The blood is coagulated by heat, and filtered through cloths in a filter press. The liquid effluent is cooked in brick basins (tank water catch basins) outdoors, heated by steam coils. The liquid is pumped into the "stick" stock and evaporated. The solid portion from the tank water catch basins is added to the blood, and sold as blood fertilizer. Any blood reaching the sewer passes through the collecting basin (C. B. 1). Offal from the cleaning of casings is rendered, but some finely divided material passes out with the wash water.

DRESSING. The scraps are all rendered. The solid portion from the rendering tanks is pressed and dried, mixed with stick, and sold as tankage. The liquid from the rendering tanks is run into the tank water catch basins, eight in number.

SMOKE HOUSE. Wash water from the floors is the only waste.

CANNING AND TRIPE ROOM. The boiling water from the canneries, and the water from scalding and cooking the tripe enter the first compartment of the long basin.

BUTTER, OLEOMARGARINE, ETC. In this department, the fats are hashed and cooked, and settled over night with salt to precipitate the moisture. The liquid is run off to the catch basin, to

be skimmed. There is also a compartment where the oleo settlings are skimmed.

FERTILIZER. Besides the blood, there are two sources of fertilizer. The manure is dried, ground, mixed, and bagged and sold for lawns. The "stick" or liquid from the cooking tank, boiled down, is added to the dried tankage, including the cleanings from the hog paunch. The tankage acts as a dryer and base to hold the liquid.

POWER PLANT. Condenser water runs out from the power plant into the south sewer.

COLD STORAGE. Pickling liquor and wash water from the floors are the wastes here.

SEWER SYSTEM. The sewerage of the Hammond Co. plant has three general subdivisions.

I. This line discharges directly into the Center avenue sewer. It receives the drainage of the toilets in the general office building, kitchen drains, downspouts from the office building and the north side of the canning and packing building, and some of the toilets in the latter.

II. The drains from the killing floors (except the paunch manure), the trimming and dressing rooms, coolers, packing and oleo departments, the laundry, and the rest of the toilets empty into the skimming tanks between the two main buildings (Catch Basin I). This is a long, shallow basin, built in eight compartments, each about 60 ft. long by 8 ft. wide, by $2\frac{1}{2}$ ft. flow depth. Each compartment has a separate outlet into a concrete conduit running alongside the basin. The grease and fat are skimmed off and taken in barrels to the tank room. The lower end of this conduit opens into a small screen chamber fitted with a removable $\frac{1}{4}$ inch mesh wire screen. This discharges into the main catch basin (Catch Basin II).

III. The third system receives the effluent of the paunch manure tank, and the condenser water from the power plant and evaporators. A 24 in. tile is the final outlet into the outlet compartment of the main catch basin.

MAIN CATCH BASIN. The main catch basin is built of concrete, 113 ft. long by 17 ft. wide inside, with a flow depth of $3\frac{1}{2}$ to 4 feet, baffled alternately, top and bottom, by timber baffles 16 ft. on centers. The upper baffles extend about 18 in. below the normal flow line, while the lower baffles rise 12 in. above the floor. The floor is flat, sloping toward the outlet. This is of no service, since the lower baffles are tight. At one time this basin was skimmed for grease.

SCREENS. Two sets of screens are in place at the outlet end of the main catch basin, both of $\frac{1}{4}$ in. mesh. One set (upstream) is fixed. The other set (downstream) is removable, built in two parts, each 4 ft. wide. Below this, a wooden stop plank forms the overflow weir of the catch-basin. A gate may be opened in this stop plank, with very large flows.

CONDENSER WATER. Midway between the two sets of screens is the suction of a pump feeding the evaporators with cooling water. This pump is run continuously while the fertilizer plant is in operation. At night this draws down the main catch basin as much as 24 in., leaving a flow depth as slight as 15 in. above the bottom.

BLOWOFF OF MAIN CATCH-BASIN. Directly under the intake pipe of the centrifugal pump is a 12 inch gate, which by-passes the screens. There was considerable flow through this. During the test the leakage was cut to a minimum with sand bags. This gate would permit any sediment on the bottom of the tank to wash out.

PAUNCH MANURE TANK. The overflow from the paunch manure expellers in the killing room passes into a shallow concrete basin 10 ft. square, on the South side of the killing house. This is baffled to make a flow under and over. The paunch manure which settles out in the rapid current is forked out by an attendant and carted away to the dump. A great deal of paunch manure escapes.

TANK WATER CATCH BASINS. These are eight in number, built of concrete, lined with brick, open, each 10 ft. by 16 ft. by 10 ft. deep, with a capacity of 11,000 gallons. Steam coils are run inside the tank, just above the bottom. The tank water is allowed to settle in these tanks for 8 to 12 hours, at a temperature of 150 to 180 deg. Fahr. Whatever grease rises to the surface is skimmed off. The water is pumped out and evaporated to stick. The solid residue is cleaned out and put into the tankage. None of these tanks are said to discharge into the sewer.

OUTLET CHAMBER. The overflow weir of the catch basin discharges into a compartment which also receives the 24 in. tile drains from the paunch manure basin, etc. A 36 in. drain carries both flows into the Center avenue sewer. This can be closed by a sluice gate at time of heavy rains. The 10 inch centrifugal pump is then operated, drawing its water from the combined flow. This discharges into the main sewer.

WEIRS. Two weirs were built, one, Weir A, to measure the flow through the main catch basin, the other, Weir B, to measure the flow from the paunch manure tank, condensers, etc. Both weirs were built with end contractions, the crest of A being 24 inches long,

and of B 12 inches long. Folding rules were set in place to serve as gages. To prevent leakage, sand bags were packed in on the floor behind the weirs. During the first day Weir B developed a serious leakage, which was finally stopped with more sand bags.

FIELD WORK. The duration of the test was 72 hours. Samples were collected and the head over the weirs read and averaged according to the following schedule:

ONE HOUR. Between 8 a. m. and 2 p. m. a portion of about 500 c. c. was collected every 10 minutes, and averaged in a gallon bottle for the hour, the weir being read also.

TWO HOURS. Between 2 p. m. and 8 p. m., a portion of about 200 c. c. was collected every 10 minutes and averaged in a gallon bottle for 2-hour periods, the weir being read also.

FOUR HOURS. Between 8 p. m. and 8 a. m., a portion of about 200 c. c. was collected every 15 minutes and averaged in a gallon bottle for 4-hour periods, the weir being read also.

KILL DURING TESTS. The kill during the tests was as follows:

Date	Cattle	Sheep	Calves	Hogs
April 20	850	1577	129	1089
21	558			1319
22				800

ANALYSES. Owing to the large number of samples, only the suspended matter of individual samples was determined. Weighted by the flow, composite samples were made in the laboratory covering typical periods. On these the oxygen consumed was determined, and special settling tests were made. The results of the analyses (table 143) show a varying content of suspended matter. The results at Weir A are consistently lower than at Weir B, with the exception of a few samples taken late in the afternoon or at night, when the catch basin was used as a condenser supply. Weir B contains a deal of paunch manure, as well as material probably drawn through from the catch basin by the condenser pump. The highest content on Weir A was 676 parts per million, on Weir B 2148 parts per million. Both figures are high, indicating insufficient settling.

CHARACTER OF SUSPENDED MATTER. The character of the suspended matter is greatly different from that in City sewage. The proportion of volatile or organic matter to fixed or mineral matter is very high, ranging from 80 to 97 per cent.

OXYGEN CONSUMED. The oxygen consumed is high on all the average special samples, being higher on "B" than on "A." In general a very large proportion of the oxygen consumed is in solution, although occasionally the reverse occurs.

SETTLING EXPERIMENTS. The settling experiments made in 500 c. c. graduates indicate that the suspended matter settles very quickly under quiescent conditions, and that a period of one hour makes a very marked reduction, the percentage reduction varying according to the amount of suspended matter present. From 35 to 73 per cent. was removed (table 146).

TESTS ON FINAL CATCH BASIN. Comparative samples collected of the influent and effluent indicate very little settling. The results are as follows:

April 21, 11 a. m. to noon.	Parts per Million. Influent.	Effluent.	Percent. Reduction.
Suspended Matter:			
Total	456	412	10
Volatile	400	...	..
Fixed	56	...	..
Oxygen Consumed:			
Total	292	...	..
Dissolved	155	...	..
Suspended	137	...	..
April 21, 3 p. m. to 4 p. m.			
Suspended Matter:			
Total	448	388	13
Volatile	380	...	..
Fixed	68	...	..
Oxygen Consumed:			
Total	146	...	..
Dissolved	108	....	..
Suspended	38	...	..

FLOW. To find the maximum flow, the sum of the readings of Weir A and Weir B should be taken. This occurred between 2:00 and 4:00 p. m., being 3.41 cu. ft. per second. The next largest flow was 2.87 cu. ft. per second between 1 and 2 p. m. Flows of approximately 2 cu. ft. per second are quite frequent in the working day. This would indicate a maximum flow of about 2¼ million gallons per 24 hours, and a flow of several hours duration of about 1¼ to 1½ million gallons daily.

TABLE 144.

HYDRAULIC ELEMENTS OF CATCH BASIN.

Flow in Cu. Ft. per Sec.	Calculated Period in Basin, Minutes.	Calculated Average Flow, Ft. per Min.	Velocity of Flow, Maximum, Ft. per Min.
0.5	223	0.51	0.79
1.0	115	0.98	1.57
1.5	79	1.43	2.33
2.0	60	1.88	3.14
2.5	49	2.30	3.91
3.0	42	2.70	4.70
3.5	36	3.14	5.56

PERIOD IN CATCH BASIN. The normal capacity of the catch basin for a depth of flow of 3½ ft. is 50,300 gallons, or 6,723 cu. ft. The period in the basin varies with the rate of flow (table 144).

A test with a flow of 2.2. cu. ft. per second at 1 p. m., April 25th, showed that some dye reaches the outlet in 15 minutes and the major portion in 20 minutes. The distribution of flow might be improved.

SLUDGE. The sludge in the main catch basin, measured on April 28th, a week after the test, showed an average depth of 0.64 ft. The calculated volume was 49 cubic yards. The sludge layer was deeper and denser at the inlet end, and shallower and apparently fresher at the outlet end. This was said to be the accumulation of a month. The sludge is said to be drained and used in the tankage.

ANALYSIS OF SLUDGE. Sludge taken from the final catch basin on April 28th, when dried, was of light brown color, containing a deal of wood fibre, mineral matter and undigested foodstuff (table 145).

It is of high specific gravity, and low moisture content compared to sewage sludges, containing a high proportion of fixed matter. The per cent. of fat and organic nitrogen are both extremely low.

TABLE 145.

Analysis of Sludge from Hammond Catch Basin.

Color: Black.
Odor: Gaseous.
Specific Gravity: 1.18.
Moisture: 61 per cent.
Volatile matter (dry basis): 34 per cent.
Fixed matter (dry basis): 66 per cent.
Nitrogen (dry basis): 0.8 per cent.
Fat (dry basis): 1.89 per cent.

CLEANING MAIN CATCH BASIN. The basin was cleaned on April 29, 1911. After the water was drained down to the level of the bottom baffles, the sludge was shoveled out. During cleaning, the emergency 12-inch gate was opened about two inches. All the liquid not pumped to the driers went out through the gate, washing away all the light sludge near the screens.

SCREENS. The placing of the screens is disadvantageous from a settling standpoint, as the pump suction draws the water through the entire area of the screen. Such coarse screens are of little service, particularly if the basins be cleaned frequently. They should be in duplicate. The clogged screen should be lifted, cleaned and re-

placed, the screenings being removed. As operated at present, the screenings fall back into the basin.

SUGGESTIONS. To improve the existing plant, certain changes are desirable, particularly in operation, from the individual standpoint.

1. It was expected in 1911 that the paunch manure would be retained by additional presses, and settling on the stripping floor. If done, this has not proved adequate, and a five mesh screen or a settling basin, or both, should be provided for the paunch manure sewer.

2. The reservoir for condenser water should be separate from the catch basin, to prevent flushing material through. It is feasible

TABLE 143.

TEST OF G. H. HAMMOND CO. PLANT.

April 20 to April 22, 1911.

April.	Time of Sampling.	Weir A		Weir B	
		Flow Cu. Ft. per Sec.	Suspended Matter, Parts per Million.	Flow, Cu. Ft. per Sec.	Suspended Matter, Parts per Million.
20	12 to 1 p. m.	0.63	372	0.54	1428
	1 to 2	1.18	676	0.79	1664
	2 to 4	1.36	396	0.40	1548
	4 to 6	0.94	368	0.48	1576
	6 to 8	0.69	296	0.50	960
	8 to 12 Mdt.	0.09	292	*	300
21	12 to 4 a. m.	D	308	*	132
	4 to 8	D	180	*	404
	8 to 9	0.32	188	0.27	1544
	9 to 10	0.88	416	0.51	1320
	10 to 11	1.16	344	0.54	1288
	11 to 12 Noon	1.28	412	0.69	2148
	12 to 1 p. m.	0.74	500	1.31	884
	1 to 2	1.34	468	1.53	1256
	2 to 4	2.01	388	1.40	1160
	4 to 6	0.90	328	0.95	308
	6 to 8	D	216	0.71	228
	8 to 12 Mdt.	D	292	0.63	264
22	12 to 4 a. m.	D	200	0.53	388
	4 to 8	D	200	0.64	244
	8 to 9	D	404	0.47	340
	9 to 10	D	364	0.45	300
	10 to 11	D	368	0.42	340
	11 to 12	0.34	378	0.49	516
	12 to 1 p. m.	D	360	0.42	416
	1 to 2	D	476	0.44	544
	2 to 4	0.10	370	0.44	480

* Weir leaked.
D Catch basin drawn from below crest of weir.

to use the present basin as a storage basin and put in the additional settling required on the joint line.

3. The roofs, toilets and human waste should be separated, and not pass through the settling basin.

4. The construction of a settling basin to care for the whole discharge, unless a common settling basin be built at the outlet of the Center avenue sewer.

TABLE 146.

SETTLING EXPERIMENTS IN LABORATORY.

Made in 500 c.c. Cylinders.

	Parts per Million.					
Sample No.	BV.	BVI.	BVII.	AVIII.	AIX.	AX.
ORIGINAL—						
Suspended Matter:						
Total	1612	972	268	468	472	240
Volatile	1488	896	256	444	432	232
Fixed	124	76	12	24	40	8
Volatile (per cent. of Total)	92	92	96	95	92	97
Oxygen Consumed:						
Total	478	360	156	256	240	122
Dissolved	138	139	74	141	130	68
Suspended	340	221	82	115	110	54
SETTLED LIQUID—						
Suspended Matter:						
Total	434	634	148	256	228	124
Volatile	396	588	142	244	222	124
Fixed	38	46	6	12	6	0
Oxygen Consumed:						
Total	232	235	111	181	179	109
Dissolved	138	139	74	141	130	68
Suspended	94	96	37	40	49	41
PERCENTAGE REDUCTION BY 1 HOUR QUIESCENT SETTLING—						
Suspended Matter:						
Total	73	35	45	45	52	48
Volatile	73	34	45	45	49	46
Fixed	69	39	50	50	85	100
Oxygen Consumed:						
Total	51	35	29	29	26	11
Dissolved	0	0	0	0	0	0
Suspended	72	57	55	65	55	24

Note. Composite samples are made up as follows:

From samples collected on

BV. April 21, 8 a. m. to noon. Weir B.
BVI. April 21, noon to 4 p. m. Weir B.
BVII. April 21, 4 p. m. to Apr. 22, 8 a. m. Weir B.
AVIII. April 21, 8 a. m. to 1 p. m. Weir A.
AIX. April 21, 1 p. m. to 4 p. m. Weir A.
AX. April 21, 4 p. m. to Apr. 22, 8 a. m. Weir A.

TABLE 146—(Continued).

SETTLING EXPERIMENTS IN LABORATORY.

Made in 500 c. c. Cylinders.

Sample No.	Parts per Million.					
	BXI.	AXII.	AIII.	AIV.	BI.	BII.
ORIGINAL—						
Suspended Matter:						
Total	372	438	400	296	1416	372
Volatile	312	352	380	276	1264	348
Fixed	60	86	20	20	152	24
Volatile (per cent. of Total)	84	80	95	93	89	92
Oxygen Consumed:						
Total	174	190	228	164	392	138
Dissolved	110	141	145	113	132	69
Suspended	64	49	83	51	260	69
SETTLED LIQUID—						
Suspended Matter:						
Total	250	248	224	176	388	126
Volatile	218	234	204	156	344	114
Fixed	32	14	20	20	44	12
Oxygen Consumed:						
Total	128	149	177	132	200	96
Dissolved	110	141	145	113	132	69
Suspended	18	8	32	19	68	27
PERCENTAGE REDUCTION BY 1 HOUR QUIESCENT SETTLING—						
Suspended Matter:						
Total	33	43	44	41	73	66
Volatile	30	33	46	44	73	67
Fixed	47	84	0	0	71	50
Oxygen Consumed:						
Total	26	21	62	20	49	31
Dissolved	0	0	0	0	0	0
Suspended	72	84	73	63	74	61

Note. Composite samples are made up as follows:

From samples collected on

BXI.	April 22, 8 a. m. to 4 p. m.	Weir B.
AXII.	April 22, 8 a. m. to 4 p. m.	Weir A.
AIII.	April 21, 1 to 4 p. m.	Weir A.
AIV.	April 21, 4 p. m. to Apr. 22, 8 a. m.	Weir A.
BI.	April 20, 12 noon to 8 p. m.	Weir B.
BII.	April 20, 8 p. m. to Apr. 21, 8 a. m.	Weir B.

5. The present catch-basin is capable of slightly improved operation.

a. The plug outlet valve should be kept closed.

b. The basin should be cleaned very frequently to prevent putrefaction.

c. The screens should be built in duplicate, with a trash basket at the bottom.

d. Distribution may be improved by a baffle at the inlet end.

6. In remodeling the present grease skimmers, a basin easier to clean can be devised,—with a false bottom. If graded sand, covered with sawdust or an inert substance like cocoanut fibre matting be used, this can be scraped and the fresh sludge removed more cheaply than by the present method of hand bailing. Duplicate basins are advisable.

APPENDIX XIII.

Report of Tests on Plant of INDEPENDENT PACKING CO. July 11 and 12, 1911.

DESCRIPTION. This plant is at Halsted and 41st streets, outside the yards, in size and operations being similar to the Pfaelzer plant. Cattle, calves, sheep and hogs are slaughtered. Dressed and smoked meats, lard, grease, tripe, sausage and commercial fertilizer are prepared for market.

OPERATION. The blood is coagulated, filtered, and used in fertilizer. Offal and scraps are rendered for grease. All tank water goes to the tank water basins and is finally evaporated. Solids are pressed, dried and ground for tankage, to be used for fertilizer filler. Pen and paunch manure are both shipped out, the paunch manure being first pressed. The operations here closely resemble those at the Hammond plant. About 200 men are employed.

CATCH BASIN. The entire flow of the plant, except that from the tank room, goes to the sewer through a catch basin built of reinforced concrete 60 ft. long by 9 ft. 10 in. wide, with a nominal flow depth of about 3 ft. 10 in. (table 147). There are four sets of baffles, each set consisting of one under- and one over-flow baffle, 15 in. apart. The underflow baffles are of concrete, and extend to 6 in. above the floor of the basin. The overflow baffles are made up of 2 in. planks dropped into guides formed of channel irons set in the concrete walls, and are 3 ft. 3 in. high.

The flow enters through a 12 in. pipe at a corner of the influent end, and flows under a wooden baffle built across this corner. At the effluent end there is a plank scum board extending across the tank and 15 in. from the end. The effluent is taken off by a 12 in. tile at the surface.

TABLE 147.

ELEMENTS OF CATCH BASIN.

Capacity, 2260 Cu. Ft.

Flow, c. f. p. s.	Nominal Period in Hours.	Av. Velocity, Ft. per Min.	Max. Velocity (Under Baffle) Ft. per Min.
0.25	2.5	0.4	3.1
0.50	1.26	0.8	6.2
0.75	0.84	1.2	9.3

TABLE 148.

CHEMICAL ANALYSIS OF THE OUTFLOW OF THE INDEPENDENT PACKING CO.

July 11 and 12, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Sus-pended.	Organic Nitrogen.	Free Ammonia.	
July 11	10 a.m. to 6 p.m.	0.40	1376	1080	296	457	310	147	152	48	370
12	10 a.m. to 4 p.m.	0.35	1016	848	168	332	250	82	184	56	590
COMPARATIVE INFLUENT AND EFFLUENT SAMPLES—12 TO 2 P. M., July 12:											
	Influent	0.30	1016	796	220	...	...	...	...	...	469
	Effluent	0.30	1164	972	192	...	...	...	...	...	...

GREASE COOKING TANKS. All the water from the tank room goes to a sump to be pumped to six grease cooking tanks, similar to those at the Hammond plant, built of reinforced concrete, 8 ft. by 12 ft. in plan, and 8 ft. deep. The tank water is settled, while the grease is skimmed off, the liquid being drained out and evaporated, the solids cleaned out, pressed and dried for fertilizer.

WEIR. A weir, 4 ft. long, with end contractions, was built on the last overflow baffle of the catch basin. Readings were taken from 10:20 a. m. to 6 p. m., July 11th, and from 10 a. m. to 4 p. m., July 12th. The maximum flow was 0.55, the minimum 0.20 cu. ft. per sec.

ANALYSIS. For the purpose of analyses a composite sample was made up for each day, in accordance with the flow for the individual samples (table 148).

The analyses of comparative samples taken over a period of two hours show an increase in suspended matter from 14 to 15 per cent, probably because the tank was septic, with sludge boiling up and passing over the effluent baffle.

SETTLING EXPERIMENT. Settling experiments, made with the effluent of the catch basin in a 500 c. c. cylinder, showed that 60 per cent. of the total suspended solids settle out in one hour under quiescent conditions.

APPENDIX XIV.

Report of Tests at Plant of LIBBY, McNEILL & LIBBY. July 17 and 18, 1911.

GENERAL. Libby, McNeill & Libby do no slaughtering, but buy fresh meats from Swift & Co. for canning purposes, preparing the same in their own cutting, refrigerating and tank rooms. All kinds of cooked specialties are manufactured, such as canned meats, extracts, etc., at the plant on 40th street. Two blocks north is a pickle factory and warehouse, where vegetables and fruits are preserved or pickled. This house was not tested.

SEWERAGE. The entire flow from the main plant, except the office and toilets, drains into the Swift 40th street sewer. The flow from the pickle factory and warehouse goes direct to the river by way of the small sewer on Packers avenue.

The meat canning house is drained by two systems, one taking all the cooking water and the other the wash water, condenser and boiler room water. The flow of the former was measured and sampled.

TABLE 149.

NOMINAL ELEMENTS OF CATCH BASIN.

Capacity, 450 cu. ft.

Flow c. f. p. s.	Period in Basin, Min.	Av. Velocity, Ft. per Min.	Max. Velocity, Ft. per Min.
0.20	37.5	1.3	2.6
0.30	25	2.0	4.0
0.40	18.7	2.7	5.4

TABLE 150.

FLOW FROM CATCH BASIN OF LIBBY, McNEILL & LIBBY.

July 17 and 18, 1911.

July.	Time.	Catch Basin, c. f. p. s.	Swift 40th St. Outlet, c. f. p. s.
17	11 to 12 M.	0.47	2.57
	12 to 2 p. m.	0.41	2.78
	2 to 4 p. m.	0.41	3.08
18	8 to 10 a. m.	0.28	2.80
	10 to 12 M.	0.36	3.08
	12 to 2 p. m.	0.47	2.80
	2 to 4 p. m.	0.47	2.92

TABLE 151.

CHEMICAL ANALYSIS OF CATCH BASIN OUTFLOW OF LIBBY McNEILL & LIBBY.

July 17 to 18, 1911.

July	Period of Collection.	Flow c. f. p. s.	Parts per Million.									
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.	Fat.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspended.	Organic Nitrogen.	Free Ammonia.		
17	10 a.m. to 4 p.m.	0.43	1740	1688	52	574	472	102	255	49	250	1040
18	8 a.m. to 4 p.m.	0.40	3800	3684	116	579	490	89	326	42	300	1412

The water from the cooking vats enters a receiving tank, 40 ft. long by 5 ft. wide, 4 ft. deep. The grease rises to the surface and is skimmed off. There are scum boards, but no flow baffles. The effluent passes on a wooden trough to a grease skimming basin about 20 ft. long by 6 ft. wide, 2 ft. deep, provided with scum boards. The flow then enters the main catch basin, 50 ft. long by $4\frac{1}{2}$ ft. wide, with a water depth of about 2 ft., baffled at top and bottom every 4 ft. The baffles are arranged in sets, the overflow baffle being between two underflow baffles which are about 15 in. apart. The underflow baffles are raised 1 ft. off the floor. Normally the overflow baffles come just below the surface (table 149):

A weir 4.5 ft. long, without end contractions, was built on one of the overflow baffles. Readings (table 150) and samples (table 151) were taken for two days during the working hours only. The samples were collected from the outlet of this basin.

The flow from the condensers and boiler room with the wash water, join the main sewer below the catch basin, passing through a small basin about 20 ft. long by 6 ft. wide, with a flow depth of about 4 ft. This is floored over by a driveway. Below the junction of the two mains there are two so-called grease traps—really manholes—about 4 ft. square. The total flow was not measured.

APPENDIX XV.

Report of Tests at Plant of MILLER & HART.

June 19 to 21, 1911.

DESCRIPTION. This is one of the smaller packing houses, doing only a fresh pork business. No meat is smoked or pickled. The usual kill is about 3,000 hogs per week from noon to 4 p. m., no killing being done on Monday or Thursday. The solid tankage, including the sludge from the catch basin, is sold to fertilizer manufacturers, without further treatment, as No. 1 Tankage. As there are no evaporators, the tank water discharges into the catch basin. The grease skimmed from the basin is rendered and sold as inedible grease; 80 men are employed.

SEWERAGE. The main flow is through the catch basin. Besides the tank water, this receives all the flow from the killing floors, wash and floor water, and most of the blood. The overflow from the reservoir, ice-machine and vacuum pumps empties into the street sewer just above the catch basin outlet. Samples of this flow show a clear water. The toilets and scald water have an outlet below the catch basin. The scald water vat holds about 20,000 gallons, and is emptied once a day.

CATCH BASIN. The catch basin is built of reinforced concrete, 45 ft. over all, 4 ft. 6 in. wide, with a flow depth of 3 ft. 6 in. The effluent is discharged by a 12 in. bell siphon, operating in a discharge chamber 9 ft. 6 in. long, separated from the rest of the tank by a tight oak partition. This makes the net length of the tank 35 ft. (table 152). The inlet of the basin is a 10 in. tile pipe discharging at the surface. Two feet from the influent end is a concrete overflow baffle, 30 in. high. Two concrete overflow baffles are built in the settling portions of the basin, and another just beyond the oak partition, all 6 in. thick, with a flow opening of

TABLE 152.

ELEMENTS OF CATCH BASIN.

Flow, c. f. p. s.	Calculated Period In Minutes.	Av. Velocity, Ft. per Min.	Max. Velocity, Ft. per Min.
0.25	36	0.95	6.6
0.50	18	1.90	13.3
1.0	9	3.80	26.7

TABLE 153.

CHEMICAL ANALYSIS OF OUTFLOW OF PLANT OF MILLER & HART.

June 19 to 21, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Sus-pended.	Organic Nitrogen.	Free Ammonia.	
June											
19	1 p.m. to 2 p.m.	....	8250	7640	880	2096	...	...	607	423	1400
20	10 a.m. to 4 p.m.	0.20	1340	1172	168	642	541	101	1364	44	800
21	10 a.m. to 12 M.	0.20	1056	964	92	1442	1397	45	3330	750	850
21	12 M. to 5 p.m.	0.20	1396	1244	152	574	467	107	390	90	500

Note. The flow figures are only approximate.

6 in. This gives the catch basin an approximate working capacity of 540 cu. ft. Through the oak partition two 4-in. pipes discharge into the siphon chamber, with inverts 40 in. above the floor of the basin. These pipes are fitted at the inlet end with elbows and long nipples turned down, so that the flow is from mid-depth, without disturbing the surface scum.

The siphon is of the bell type, with a 12-in. discharge pipe and bell 22 in. in diameter by 32 in. deep. The discharge depth varies widely from 27 to 42 in., with an average of 3 ft. While sampling at two other inspections, the siphon was not in working order. By trial the average interval between discharges, while killing was found to be about 10 minutes, making an approximate discharge averaging 12.5 cu. ft. per minute, or 0.2 c. f. p. s. This agrees with other plants of the same size. During the morning and on days when no killing is done, there is practically no flow, so that the duration of flow at this rate is probably about 4½ hours for four days a week.

Observations made in April give a period of siphon discharge as short as 4 minutes, or a maximum flow of about 0.80 c. f. p. s.

APPENDIX XVI.

Report of Tests on Plant of
NELSON MORRIS AND CO.
June 15 to 17, 1911.

PLANT. Nelson Morris & Co. carry on a typical packing business of the large type, with divided layout, the hog killing plant being separate. Hogs, cattle, calves and sheep are killed. Dressed, smoked and canned meats are prepared, besides glue, oleomargarine, tripe, soap fats, grease, hair, fertilizer and ammonia.

SUBDIVISION OF PLANT. The hog houses and allied departments are located at Center and Exchange avenues. The beef house and allied departments are located between 42d and 44th streets, between Loomis street and Ashland avenue. Since the outlets are entirely distinct, the plants will be considered separately.

CAPACITY. The nominal average daily capacity of the house is given in head slaughtered, as:

Cattle	700
Calves	250
Sheep	2,000
Hogs	1,500

BEEF DIVISION.

PLANT. This division comprises the slaughter house for cattle, calves and sheep, as well as oleo, tank, tripe, bone and fertilizer houses, the glue factory, hair house and ammonia house, and stables. There is no wool pullery.

SLAUGHTERING. The actual daily kill may run as high as,—

Cattle	1,350
Calves	500
Sheep	2,500

During the test from June 15 to 17 the kill was as follows:

Animals.	June 15.	June 16.	June 17.
Cattle	924	499	..
Calves	130	...	..
Sheep	2,202	1,162	..

BLOOD RENDERING. The blood is collected and dried, being sold for fertilizer. All the scraps are rendered, the solid portions being pressed and dried, mixed with stick and sold as tankage. The liquid from the rendering tanks is evaporated and dried.

PENS. There are no pens, except the space reserved for the immediate kill.

PAUNCH MANURE. The paunch manure from the cattle, calves and sheep is said to be saved and dried for filling fertilizer. Tanks are provided to settle the heaviest run of paunch manure, but much escapes to the sewers, as shown by inspection of the 44th street samples.

AMMONIA HOUSE. Ammonia is made from gas-house liquor and scraps. The waste liquid is very high in suspended matter, receiving practically no settling. The flow is small compared with the other houses, and is stated to average 40,000 gallons a week, or about 10,000 gallons a day.

SEWER SYSTEM. This part of the Morris & Co. plant has two main outlets, one to the south through a 36-inch brick sewer on 44th street into Ashland avenue, the other on 42d street into Swift's 42d street sewer, thence into Ashland avenue.

System I. The 36-in. brick sewer on 44th street receives the outflow and wash water from the killing floors, fertilizer condenser water, ice and refrigerator plants, pens, paunch manure overflow, bone, glue and hair houses and stables. On this sewer proper there are no catch basins. A few skimming vats are located inside the buildings.

System II. The waste waters containing grease are gathered together in this line, including the waste from the oleo and butterine factories, the tank rooms, trimming and cutting floors, and the killing floors. The outlet is through the grease skimming basin and catch basin, into the 42d street sewer.

MINOR OUTLETS. In addition to the main sewers there are three smaller ones, all emptying into the 42d street main, including the drain from the ammonia plant, a 12-in. box sewer from the office toilets, and a small tile sewer from the toilets in the general office and from the loading dock. Both the latter also receive storm water. During the time of the test the flow was very small.

The sewer from the main office toilets empties into a catch basin which is very stagnant, being practically an open septic tank. There are two 1-in. wire screens at the outlet end, but on account of the small flow they are of little use except at time of rain. The basin is of wood, 40 ft. long by 4 ft. wide inside with a nominal flow depth of 3 ft., cross-baffled every 8 ft. The sludge is finely divided, being gray in color.

GREASE SKIMMER AND CATCH BASIN. The main portion of the flow, rich in fats, enters a grease skimming basin 4 ft. wide by 90 ft. long, approximately 4 ft. flow depth, provided with 12 surface

baffles cut off 10 in. above the bottom. These hold back the grease. The inlet from the butterine factory is at the middle of this basin. The outflow enters the main catch basin, about 88 ft. long by 14 ft. wide, inside dimensions, with a nominal flow depth of 4 ft. It is divided into two long compartments each provided with surface baffles about every 6 ft. extending down to 8 in. above the bottom. Directly adjacent is a bottom baffle 22 in. high. Both the grease skimmer and the catch basin are skimmed, the solid matter on the bottom being removed daily by buckets. The outlet is provided with three screens, counterbalanced and locked down, each of ½ in. mesh.

OPERATION. During the operation of the plant one man is kept busy skimming grease on the long basin, and one at the catch basin.

WEIR. The weir was built just outside the screen farthest downstream. The crest was 24 in. wide, 4 ft. 4 in. above the bottom of the basin, with two end contractions.

PERIOD IN CATCH BASIN. The catch basin flow is not disturbed by condenser pumping. The nominal period may be calculated from the flow over the outlet weir (table 154).

TABLE 154.

ELEMENTS OF CATCH BASIN.

Flow, Cu. Ft. per Sec.	Calculated Time in Basin, Minutes.	Calculated Average Velocity, Ft. per Min.	Calculated Maximun Velocity, Ft. per Min.
0.25	365	0.5	2.8
0.50	185	1.0	5.6
0.75	125	1.4	8.3
1.00	95	1.8	11.0
1.5	65	2.7	16.5
2.0	49	3.6	22.0

CHEMICAL ANALYSES OF AMMONIA WASTE.

Description.	Parts per Million. Collected June 15.	Collected June 16.
Suspended Matter:		
Total	65920	105952
Volatile	2516	5192
Fixed	63404	100760
Oxygen Consumed:		
Total	1843	5450
Soluble	1753	4820
Suspended	90	630
Organic Nitrogen	110	288
Free Ammonia	98	120
Alkalinity	3790	6690

AMMONIA HOUSE. The waste contains large amounts of suspended mineral matter, largely carbonates. Nearly all the oxidizable material in solution is sulphides.

Settling experiments on these samples showed that the matter settles very quickly, clearing remarkably in 5 minutes. 500 c. c. deposited a volume of settled material of 150 c. c. with a specific gravity of 1.21 after 5 hours compacting. The result of the settling test was as follows:

Description.	Parts per Million. Before Settling.	After Settling.
Suspended Matter:		
Total	65920	118
Volatile	2516	40
Fixed	63404	78

Based on the amount of sediment by volume from 1¾ to 2 in. of solids in 2 to 9 in. total depth—say 20 to 25 per cent. solids, with a discharge of 40,000 gallons per week, a daily discharge of 6,667 gallons may be estimated, of which 1,333 gallons are solid. This is equivalent to 6.61 cu. yds. daily, or on the basis of 300 days a year, 1,983 cu. yds. of material in place. Based on an average solid content of 86,000 p. p. m., every gallon of liquid would contain 0.716 lbs. of solid. Hence, in 300 days 1,432,000 lbs. would be discharged, or 716 tons of dry material, or 1,060 cu. yds. based on a weight in place of 100 lbs. per cu. ft. with 50 per cent. moisture.

FLOW. The flow at the main catch basin is given in table 155, calculated from the average of readings taken every 20 minutes:

TABLE 155.

FLOW IN MAIN CATCH BASIN.

June.	Time.	Flow, Cu. Ft. per Sec.
15	12 to 2 p. m.	0.12
	2 to 4 p. m.	0.86
	4 to 6 p. m.	1.00
	6 p. m. to 16, 8 a. m.	0
16	8 to 10 a. m.	0.12
	10 to 12 M.	0.96
	12 to 2 p. m.	1.27
	2 to 4 p. m.	1.79
	4 to 5 p. m.	1.75
	5 p. m. to 17, noon	0

TABLE 156.

CHEMICAL ANALYSIS OF OUTLET "G." MORRIS & CO.

June 15 to 17, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Sus-pended.	Organic Nitrogen.	Free Ammonia.	
June											
15	12 to 4 p.m.	0.49	860	724	136	339	211	128	120	88	580
15	4 p.m. to 16, 8 a.m.	0	356	276	80	179	122	57	57	55	400
16	8 a.m. to 4 p.m.	1.03	928	820	108	333	228	105	128	54	440
16	4 to 8 p.m.	0.43	620	568	52	345	230	115	123	37	440
16	8 p.m. to 17, 8 a.m.	0	380	344	36	190	120	70	49	53	380
17	8 a.m. to 12 Noon	0	448	352	96	229	146	83	44	52	280

TABLE 157.

CHEMICAL ANALYSIS OF 44TH ST. OUTLET. MORRIS & CO.

June 15 to 16, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspended.	Organic Nitrogen.	Free Ammonia.	
June 15	12 to 4 p.m.	0.98	1944	1696	248	582	221	361	108	29	430
	4 to 8 p.m.	0.24	672	572	100	315	157	158	73	26	280
	8 p.m. to 8 a.m.	0.16	980	884	96	304	109	195	90	19	240
16	8 a.m. to 4 p.m.	0.70	1244	1076	168	319	203	116	86	36	330
	4 p.m. to 8 a.m.	0.37	392	268	124	158	95	63	27	21	170
	8 a.m. to 12 M.	0.72	632	436	196	330	123	207	40	30	250

SETTLING EXPERIMENT. A test made on the average sample collected between 12 and 2 p. m. on June 15th, showed the following reduction of suspended matter in 2 hours:

Description.	Parts per Million. Before Settling.	After Settling.	Percentage Reduction.
Suspended Matter:			
Total	404	300	26
Volatile	360	272	24
Fixed	44	28	36

HOG HOUSE.

PLANT. The business carried on is the killing, dressing and curing of pork, as well as the preparation of by-products, such as the rendering of grease and lard.

The capacity is 1,500 hogs daily on the yearly average, with a maximum kill of 5,000. During the test, June 13 to 15, the kill was as follows:

Date.	Hogs.
June 13	2,902
" 14	841
" 15	2,058

SEWERAGE SYSTEM. The plant is drained by three lines of sewers. One receives the toilets, discharging direct to the Exchange avenue sewer. The other two conduct the waste into the last catch basin, where the sewage was sampled before entering the Exchange avenue sewer. Subsidiary grease skimming basins are provided on each line, 5 on one and 1 on the other.

CATCH BASIN. The catch basin at the hog house is built of wood, 26.5 ft. long by 4 ft. wide, with a nominal flow depth of 2.25 feet. During the test the flow depth averaged about 3 ft., as the crest of the weir was 2 ft. 11 in. above the bottom of the basin. The weir was 3 ft. wide with 2 end contractions. There are 6 baffles equally spaced, extending down to about 6 in. above the bottom; 3 screens are provided at the outlet, one of ¼-in. mesh, and two of ¾-in. mesh. During the period of the test the larger mesh screens were in front of the small mesh.

CLEANING SCREENS. During the test the screens were cleaned twice a day by lifting one at a time. The matter collected was dumped on the ground and carted away to the tank room. The amount was small. There was considerable leakage around the screens, large chunks of material appearing below, apparently larger than the mesh of the screen.

PERIOD IN CATCH BASIN. The flow in the final catch basin is rapid, and undisturbed by any pumping. The nominal period may be calculated from the flow over the outlet weir (table 158).

TABLE 158.

ELEMENTS OF CATCH BASIN.

Flow, Cu. Ft. per Sec.	Calculated Time in Basin, Min. Sec.	Calculated Average Velocity Ft. per Min.	Calculated Maximum Velocity, Ft. per Min.
0.50	10—48	2.5	15
1.00	5—33	4.8	30
1.50	3—47	7.0	45
2.00	2—53	9.2	60

MANURE. Most of the manure is saved. The hog paunch manure is used for filler in fertilizer, being separated and pressed, but a deal escapes to the catch basin by the overflow.

FLOWS. The flow at the hog house is given in table 159, being calculated from average readings taken every 20 minutes. The maximum average flow is 1.23 cu. ft. per second. At no time was a zero flow observed.

TABLE 159.

FLOW OF HOG HOUSE, MORRIS AND CO.

June.	Time.	Flow, Cu. Ft. per Sec.
13 Tuesday	12 to 2 p. m.	1.02
	2 to 4 p. m.	1.09
	4 to 8 p. m.	0.69
	8 to 12 Mdt.	0.36
14 Wednesday	12 to 4 a. m.	Not taken
	4 to 8 a. m.	Not taken
	8 to 10 a. m.	0.89
	10 to 12 M.	1.08
	12 to 2 p. m.	1.23
	2 to 4 p. m.	0.89
	4 to 8 p. m.	0.58
	8 to 12 Mdt.	0.31
15 Thursday	12 to 4 a. m.	0.22
	4 to 8 a. m.	0.47
	8 to 10 a. m.	0.95
	10 to 12 M.	0.95
	12 to 2 p. m.	0.95
	2 to 4 p. m.	0.95

SAMPLES. Small portions were collected every 20 minutes day and night. From 8 a. m. to 4 p. m., about 500 c. c. was collected every 20 minutes, and averaged every 2 hours. From 4 p. m. to 8 a. m. about 250 c. c. was collected every 20 minutes, and averaged every 4

TABLE 160.

CHEMICAL ANALYSIS OF OUTFLOW OF HOG HOUSE. MORRIS & CO.

June 13 to 15 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspended.	Organic Nitrogen.	Free Ammonia.	
June											
13	Noon to 8 p.m.	0.87	956	900	56	446	265	181	123	39	280
13	8 p.m. to Mdt.	0.36	172	138	34	133	44	89	35	16	260
14	8 a.m. to 4 p.m.	1.02	1004	884	120	632	434	198	403	59	440
14	4 p.m. to 8 p.m.	0.58	748	636	112	388	295	93	176	32	360
14	8 p.m. to 15, 8 a.m.	0.33	94	77	17	158	107	51	98	14	240
15	8 a.m. to 4 p.m.	0.95	1012	852	160	397	326	71	352	64	...

hours. Composite samples were made up in the laboratory, based on the average flow, and grouped in accordance with the flow and physical appearance of the field samples.

ANALYSES. The results of the analyses of the composite samples are given in table 160.

SETTLING EXPERIMENTS. A fresh sample was collected on June 19th for experiment, under quiescent conditions. The amount of sludge collecting at the bottom of the glass indicated that practically all the settling suspended matter came down in the first hour.

TABLE 161.

REDUCTION OF SUSPENDED MATTER.

Description.	Parts per Million.		Percentage Reduction.
	Before Settling.	After Settling.	
Total	1264	468	63
Volatile	1060	408	62
Fixed	204	60	71

PERIOD IN BASIN. The calculated period in the present final basin is around 5 minutes, and the actual period much shorter, so that practically no settling occurs. The baffles are likewise so placed that settlings are swept along and out.

SCREENS. The usefulness of the present screens is practically nil.

Spaces of one inch or more in each side of the screen slides, and underneath, allow any large solid matter to pass. Chunks of flesh, hide, hair, etc., are visible plainly in the flow to the sewer below the screens. These are not included in the chemical analysis.

APPENDIX XVII.

Report of Tests on Plant of NORTHWESTERN GLUE COMPANY. June 22 and 23, 1911.

PLANT. The Northwestern Glue Co. manufactures glue, white and brown grease, inedible tallow and neatsfoot oil, selling the solid tankage to fertilizer manufacturers. No killing is done. Fresh stock, scraps, bones, hoofs, etc., are bought from the various packing houses. The sewage consists largely of wash water, the overflow and liquid from the cooking vats, with a deal of condenser water. The tank water is said to be evaporated.

CATCH BASINS. There are two timber catch basins one 13 ft. long by 7 ft. wide inside, with a flow depth of 3½ ft. and a longitudinal baffle, on each side of which are 4 sets of under and overflow baffles, making a total of nine sets, including the one at the end of the longitudinal baffle. There are no screens. The effluent enters a second basin 14 ft. long by 6 ft. wide, having a maximum depth of only 12 in. This has four sets of baffles, which act merely as scum-boards. Below this basin, along the sewer, are two so-called catch basins, or clean-out manholes, 6 ft. square, with a flow depth of 12 in.

WEIR AND SAMPLES. A 2-ft. weir with end contractions was built on the overflow baffle at the effluent end of the first basin. Readings were taken every 20 minutes, the samples being taken each time at the last clean-out manhole (table 163).

PERIOD IN BASIN. The settling period in the first catch basin may be calculated from the flow over the weir.

The maximum velocity is taken as the velocity under one of the underflow baffles, with its lower edge raised 4 in. off the floor.

ANALYSES. Composite samples were made in the laboratory for each day.

TABLE 162.

NOMINAL ELEMENTS OF CATCH BASIN.

Capacity, 317 Cu. Ft.

Flow, c. f. p. s.	Period in Basin, Min.	Av. Velocity, Ft. per Min.	Max. Velocity, Ft. per Min.
0.10	53	0.49	5.2
0.20	26.5	0.98	10.4
0.30	17.6	1.47	15.6

TABLE 163.

CHEMICAL ANALYSIS OF OUTFLOW OF NORTHWESTERN GLUE COMPANY.

June 22 and 23, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Sus-pended.	Organic Nitrogen.	Free Ammonia.	
June											
22	10 a.m. to 4 p.m.	0.20	712	560	152	438	303	135	378	54	280
23	8 a.m. to 4 p.m.	0.16	832	496	336	440	352	88	342	31	192

APPENDIX XVIII.

Report of Tests at Plant of PEOPLES PACKING COMPANY.

June 26, 1911.

PLANT. The Peoples (or Inland) Packing Co., located at 1546 W. 47th street, slaughter about 100 hogs daily. The principal business is cooked specialties, such as boiled hams, loin rolls, etc. All paunches are sold whole. No blood is saved. Casings are cleaned and packed. All scraps are rendered for grease. Lard is prepared. All solid tankage is sold, the liquid portion going to the catch basin.

CATCH BASIN. The wooden catch basin, 16 ft. long by 4 ft. wide, with a flow depth of about 3½ ft., is not provided with screens and was in a very filthy condition. During the morning there is practically no flow.

READINGS AND SAMPLES. Between noon and 4 p. m. the water meter was read, samples being collected from the outlet of the catch basin (table 164).

SETTLING EXPERIMENTS. Settling experiments with the effluent of the catch basin show that nearly 75 per cent. of the total suspended solids deposit in 1 hour, under quiescent conditions.

TABLE 164.

CHEMICAL ANALYSIS OF THE OUTFLOW FROM THE PEOPLES PACKING CO.

June 26, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Sus-pended.	Organic Nitrogen.	Free Ammonia.	
June 26	12:40 to 2 p.m.	0.08	1428	1144	284	470	321	149	288	45	320
	2 p.m. to 4 p.m.	0.54	1004	828	176	455	344	111	308	36	320

APPENDIX XIX.

Report of Tests on Plant of
LOUIS PFAELZER AND SONS.
June 27 and 28, 1911.

PLANT. The Pfaelzer plant is outside the yards, at Halsted and 40th streets. A general packing business is carried on, handling fresh and smoked meats, lard, grease, oleo stock and fertilizer. The plant is new, built in 1910, and is housed in one building. About eighty men are employed.

CAPACITY. The nominal daily capacity was given as—

Cattle	200
Sheep	200
Calves	20
Hogs	150

BLOOD, RENDERING, ETC. The blood is collected, coagulated and filtered, the solid part being used in the fertilizer and the liquid being run into the catch basin without evaporating. All scraps of fat, offal, etc., are rendered. The solid tankage is pressed and dried, but the liquor is not saved. All casings are cleaned and packed, but no sausage is made. There is a smoke house, but no tripe room.

MANURE. All pen and paunch manure is shipped out. The paunch manure is pressed, the water from the press going to the catch basin.

CATCH BASIN. Except for human sewage, all the waste, including the floor and wash water from the killing and cutting floors and tank rooms, scald water, paunch manure overflow, part of the blood, and the condenser water, goes to the catch basin. This is concrete, built in the basement of the building, "U" shaped in plan, with a walk between the two parts. The inside dimensions of each

TABLE 165.

NOMINAL ELEMENTS OF CATCH BASIN.

Capacity, 860 Cu. Ft.

Flow, c. f. p. s.	Period in Basin, Min.	Av. Velocity, Ft. per Min.
0.10	143	.52
0.20	72	1.04
0.30	48	1.56

TABLE 166.

CHEMICAL ANALYSIS OF OUTFLOW OF PLANT OF L. PFAELZER & SONS.

June 27 to 28, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Sus-pended.	Organic Nitrogen.	Free Ammonia.	
June											
27	10 a.m. to 4 p.m.	0.18	320	276	44	242	148	94	68	15	200
28	8 a.m. to 4 p.m.	0.21	420	392	28	323	214	109	129	12	260

half are, length 39 ft. 6 in., width 3 ft. 6 in., and flow depth 3 ft. The total length of flow is 82 ft. There are no screens. The effluent flows over a tight wooden baffle across the end, out through an 8-in. tile in the floor, which empties into the Halsted street sewer. There are scum-boards extending a few inches below the surface. As the basin is entirely in-doors the temperature is at all times very high.

READINGS AND SAMPLES. A 3-ft. weir, with end contractions, was built on the effluent baffle. Samples and readings were taken at 20-minute intervals during the day hours on June 27th and 28th.

ANALYSES. In the laboratory, composite samples were made up for each day (table 166). No settling experiments were made.

APPENDIX XX.

Report of Tests at Plant of SIEGEL-HECHINGER.

July 19 and 20, 1911.

PLANT. In the Siegel-Hechinger plant, located at 38th place and Gage street, about 600 head of cattle and 200 calves are slaughtered weekly and dressed for the local trade. The only by-products manufactured are inedible tallow and tankage, which is sold green. No evaporator is used, the tank liquid going direct to the catch basin. The blood is collected and sold after being cooked. All the wash and floor water, bile, etc., goes to the catch basin. The cattle paunches are ripped open and the manure sent through a chute to a wooden tank over the catch basin where the water is allowed to drain off. The manure is then hauled away.

CATCH BASIN. The catch basin is built of concrete, 34 ft. long by 4½ ft. wide, with a nominal flow depth of 27 in. Spaced about 6 ft. apart are scum boards, and wooden overflow baffles 24 in. high. There are no screens.

WEIR AND SAMPLES. A weir 2 ft. long, with 2 end contractions, was built on an overflow baffle (table 167). Readings and samples were taken during two working days, the samples being collected from a small manhole just below the basin (table 168). The sewage flows into the 35th street sewer.

SETTLING EXPERIMENTS. In settling experiments on the effluent of the catch basin 70 per cent. of the total suspended solids settled out in one hour under quiescent conditions.

TABLE 167.

NOMINAL ELEMENTS OF CATCH BASIN.

Flow, c. f. p. s.	Period in Basin, Min.	Av. Velocity, Ft. per Min.
0.05	115.0	0.30
0.10	56.7	0.59
0.20	28.7	1.18

TABLE 168.

CHEMICAL ANALYSIS OF OUTFLOW FROM THE SIEGEL-HECHINGER PLANT.

July 19 and 20, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Sus-pended.	Organic Nitrogen.	Free Ammonia.	
July											
19	8 a.m. to 4 p.m.	0.12	528	456	72	421	316	105	139	45	510
20	10 a.m. to 4 p.m.	0.04	1640	1460	180	602	490	112	555	149	1500

APPENDIX XXI.

Report of Tests at Plant of
STANDARD SLAUGHTERING CO.

(Eli Pfaelzer.)

July 13 and 14, 1911.

PLANT. In the Standard Slaughtering Co. plant at 40th and Butler streets about 600 head of cattle are killed and dressed weekly. No calves, sheep or hogs are handled. All meat is sold fresh. The only by-products are grease and tankage, the latter being sold green. The blood is cooked and pressed dry, being sold to the fertilizer manufacturers along with the tankage. Both pen and paunch manure are shipped. There are no manure presses.

CATCH BASIN. The so-called catch basin is a large manhole, about 8 ft. long by 2½ ft. wide, flowing about 24 in. deep. There are three overflow baffles and scum boards. At the outlet is one ¼-in. mesh wire screen.

WEIR AND SAMPLES. A weir was built on one of the baffles with a crest 1.5 ft. long, with two end contractions. Samples and readings were taken during two working days, the samples being collected below the scum (table 169).

TABLE 169.

CHEMICAL ANALYSIS OF OUTFLOW FROM PLANT OF STANDARD SLAUGHTERING CO.

July 13 and 14, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspended.	Organic Nitrogen.	Free Ammonia.	
July											
13	10 a.m. to 4 p.m.	.03	532	484	48	374	332	42	224	32	...
14	8 a.m. to 4 p.m.	.03	484	400	84	451	373	78	142	42	520

APPENDIX XXII.

Report of Tests on Plant of SULZBERGER SONS CO.

May 12 and 13 and June 29 to July 1, 1911.

LOCATION. The plant of the Sulzberger Sons Co. is located to the west of the Yards and Ashland avenue, lying between Ashland avenue and Robey street, just north of 42d street.

PLANT. The Sulzberger Sons Co. is a packing house of the large type, slaughtering hogs, sheep and cattle, preparing dressed, smoked and canned meat, and producing a number of by-products, such as oleomargarine, tripe, soap fats, grease and fertilizer.

SEWERS. The sewerage system of the Sulzberger Co. has two separate divisions, one known as the "grease" sewer, the other as the "red" sewer. There is a 30-in. outlet to Ashland avenue sewer, common to both, and an outlet direct to Bubbly Creek at the west of the plant.

GREASE SEWERAGE SYSTEM. This system drains all the slaughtering floors, trimming rooms, packing, rendering, oleo, lard and sausage departments, as well as the bone house and pork coolers. The outflow of the individual departments or floors passes through skimming basins. The collective discharge is through a concrete catch basin, which empties into the red sewer.

RED SEWER. The red sewer receives practically all the sewage not containing grease, including the downspouts, toilets, warehouses, a large proportion of the wash water and water from the condensers and the stock pens. Whenever the stock pens are flushed with a hose, a deal of manure reaches the sewer. The water from the brine overflows, hide room, casing department and paunch manure outflow, as well as the lard, sausage, ham cure and smoke house all drain into this system. This system discharges direct into Ashland avenue sewer without any treatment.

CATCH BASIN. The final catch basin at the outlet end of the "grease" sewer is built of reinforced concrete, 8 ft. wide by 100 ft. long, with a flow depth of about 3 ft., baffled every 10 ft. 8 in. with baffles rising 2 ft. 6 in. above the bottom. Up-stream from all but the first compartment is a scum board extending down within 6 in. of the bottom. Hence surface accumulations are held back, and cooled, but all settling particles are swept along through the basin.

The first two compartments have no screen board, but retain the heaviest particles by the bottom boards.

PUMPING. The catch basin supplies a condenser pump, which draws from the last compartment. As the tests were run in the daytime, there was an excess flow over that required by the pump. This practice undoubtedly disturbs the catch basin. The pump supplies the drier-condensers, the final flow entering the red sewer.

SCREENS. Prior to April 10, 1911, only one screen of ¾-in. mesh was in place just inside the outlet baffle. The suction of the pumps was also protected by screens. A sluice gate on the bottom was kept open to allow any accumulation of solid matter to wash out. During the test four screens were used, the first three of wire of ½-in. mesh; the last built in two halves, one of wire ¼-in. mesh, the other of boiler plate with ¼-in. openings. The last set alone is provided with handles for lifting. At present (1911) they are being cleaned with scrapers by two men, the material removed being pushed back into the basin.

WEIRS. For the purpose of the tests, weirs were built at the inlet and outlet ends of the basin by placing thin-edged crests on the top of the first baffle and the outflow baffle. The first weir was without end contractions. Owing to a handle projecting in the middle of the second weir, it was considered to have two end contractions (table 172).

ANALYSES. With the large number of samples, only the suspended matter in individual samples was determined. Weighted by the flow, special composite samples were made in the laboratory covering typical periods of the test, on which the oxygen consumed was determined.

CATCH BASIN OUTLET. The analyses of suspended matter at the outlet of the catch basin show a content somewhat lower than the highest found on the preliminary short time test of 1 hour. The content of suspended matter averaged from 668 to 1,048 parts per million, an amount from 4 to 7 times that in city sewage. Much gross material passes through visible to the eye, which is not included in the analysis (table 172).

RED SEWER OUTLET. The samples collected from the red sewer at two different times contained from 844 to 1,224 parts per million suspended matter. This sewer is 30 in. diameter, carrying a flow probably as great as that in the grease sewer and should certainly be settled. This sewer, connected with the paunch manure outlet, at times received much material in suspension (table 170).

TABLE 170.

ANALYSIS OF RED SEWER.

Determination.	Parts per Million.	
	May 12, 1:10 p. m.	May 13, 10:30 a. m.
Suspended Matter:		
Total	1224	844
Volatile	1120	760
Fixed	104	84
Oxygen Consumed:		
Total	335	293
Dissolved	182	150
Suspended	153	143
Chlorine	784	650

COMPARISON OF INFLUENT AND EFFLUENT OF CATCH BASIN. Average samples, collected during one hour on two occasions, show little or no improvement in the catch basin as shown below.

TEST. 11 TO 12 A. M. MAY 12.

TOTAL FLOW 2.88 CUBIC FEET PER SEC.

NOMINAL PERIOD 14 MINUTES.

Determination.	Result in Parts per Million.		Reduction, Per Cent.
	Influent.	Effluent.	
Suspended Matter:			
Total	632	696	Increase
Volatile	592	656	"
Fixed	40	40	0
Oxygen Consumed:			
Total	310	351	Increase
Dissolved	216	214	1
Suspended	94	137	Increase
Chlorine	1580	1610	"

TEST. 11 TO 12 A. M. MAY 13.

TOTAL FLOW 2.53 CUBIC FEET PER SEC.

NOMINAL PERIOD 16 MINUTES.

Determination.	Parts per Million.		Reduction, Per Cent.
	Influent.	Effluent.	
Suspended Matter:			
Total	844	780	8
Volatile	784	732	7
Fixed	60	48	20
Oxygen Consumed:			
Total	363	372	Increase
Dissolved	274	272	1
Suspended	89	100	Increase
Chlorine	2166	2016	7

PERIOD OF FLOW. The period of flow is shown approximately by the amounts passing over the inlet weir.

TABLE 171.

HYDRAULIC ELEMENTS OF CATCH BASIN.

Flow, Cu. Ft. per Sec.	Calculated Time in Basin, Min.	Calculated Average Velocity, Ft. per Min.	Calculated Maximum Velocity, Ft. per Min.
0.5	77	1.3	7.5
1.0	39	2.6	15.
1.5	26	3.8	22.5
2.0	20	5.0	30.
2.5	16	6.2	37.5
3.0	14	7.4	45.
3.5	12	8.5	52.5
4.0	10	9.7	60.

The calculated maximum velocity is figured on the velocity underneath a scum board, with the bottom edge raised 6 in. off the bottom (table 171). These high velocities explain why the deposits wash through and out.

The actual period of flow was tested by dye on May 16th. The color was strong at the outlet after 6½ min. The actual period of flow is usually less than the calculated period, because of the difficulty of obtaining complete displacement. The calculated periods in the catch basin average from 12 to 16 minutes, and are too short for proper settling, particularly with the high velocities.

TABLE 172.

SULZBERGER SONS CO.

Tests on May 12 and 13, 1911.

May.	Time of Sampling.	Outlet Weir. Flow, Cu. Ft. per Sec.	Outlet Weir. Suspended Matter. Parts per Million.	Inlet Weir. Flow, Cu. Ft. per Sec.
12	10 to 11 a. m.	1.36	808	2.64
	11 to 12 Noon	1.52	696	2.88
	12 to 1 p. m.	1.52	692	2.48
	1 to 2 p. m.	2.32	668	2.64
	2 to 4 p. m.	2.48	716	3.04
	4 to 6 p. m.	1.95	664	Submerged
	6 to 8 p. m.	2.61	888	3.32
13	8 to 9 a. m.	1.32	772	2.46
	9 to 10 a. m.	1.49	924	2.67
	10 to 11 a. m.	1.92	884	2.51
	11 to 12 Noon	2.07	780	2.53
	12 to 1 p. m.	1.70	776	2.25
	1 to 2 p. m.	2.21	712	2.81
	2 to 4 p. m.	2.03	1048	2.53

CATCH BASIN SLUDGE. A sample of the deposit collected from the catch basin on May 13, at 10 a. m., had a black color with a putrid odor. The analysis shows a liquid sludge, very high in volatile matter, containing some organic nitrogen and fat, much higher than in typical sludge from city sewage.

SLUDGE ANALYSIS.

Color: Black.
Odor: Putrid.
Specific Gravity: 1.03.
Moisture: 83.2 per cent.
Calculated to dry weight:

	Percent.
Volatile matter	87.5
Fixed matter	12.5
Nitrogen	3.6
Fat	5.7

SETTLING EXPERIMENTS. Experiments on settling the effluent in a 500 c. c. cylinder show that from 22 to 49 per cent. of the effluent of the present catch basin settles out in 1 hour, under quiescent conditions, and that 60 per cent. of the effluent of the "red" sewer settles out in 1 hour under quiescent conditions (table 173).

Second Test.

June 29 to July 1, 1911.

FIELD WORK. The second test was made from 8 a. m., June 29, to 8 a. m., July 1, with two weirs, one on the outlet baffle of the catch basin, being weir "A" of the previous test, and one in the last manhole on the "Red" sewer line. As the condensing water pump in the catch basin was not run during the test, no influent weir was necessary. The weir in the "Red" sewer was made 20 in. wide with two end contractions, the crest being 13½-in. above the sewer invert (table 174).

GREASE SKIMMING TANKS. On the grease sewer, back of the main catch basin, are nine grease skimming tanks besides the old "general receiving basin." All are timber, 5 ft. wide, with a flow depth of 2 ft. 6 in., baffled with scum boards. The receiving basin is 75 ft. long. The grease tanks have lengths, respectively, from the back of the receiving basin of 28½ ft., 30 ft., 30 ft., 40 ft., 40 ft., 30 ft., 29 ft., 31 ft., and 30 ft.

1,800 to 2,000 men are employed at the plant. All human sewage enters the "Red" sewer.

TABLE 173.

SULZBERGER SONS CO.

Settling Experiments in 500 c. c. Cylinders.

Sample.	Parts per Million.			
	AI.	AII.	AIII.	RI.
ORIGINAL—				
Suspended Matter:				
Total	696	952	692	860
Volatile	636	856	628	776
Fixed	60	96	64	84
Oxygen Consumed:				
Total	363	359	266	345
Dissolved	277	276	183	158
Suspended	86	83	83	187
SETTLED LIQUID—				
Suspended Matter:				
Total	412	482	542	352
Volatile	380	438	482	320
Fixed	32	44	60	32
Oxygen Consumed:				
Total	351	347	261	258
Dissolved	277	276	183	158
Suspended	74	71	78	100
PERCENTAGE REDUCTION BY 1 HOUR QUIESCENT SETTLING—				
Suspended Matter:				
Total	41	49	22	59
Volatile	40	49	23	59
Fixed	47	54	6	62
Oxygen Consumed:				
Total	3.3	3.4	1.9	25
Dissolved	...	...	...	...
Suspended	14	15	6	47

Note. Composite samples are made up as follows:

AI. From samples collected between 10 a. m. and 8 p. m. May 12, Outlet of Catch Basin.

AII. From samples collected between 8 a. m. and 4 p. m. May 13, Outlet of Catch Basin.

AIII. Sample collected between 12 and 1 p. m. May 12, outlet of catch basin.

RI. From samples collected from "Red" sewer May 12 and 13.

TABLE 174.

CHEMICAL ANALYSIS OF OUTFLOW AT PLANT OF SULZBERGER & SONS.

Second Test June 29 to July 1, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Sus-pended.	Organic Nitrogen.	Free Ammonia.	
June											
	CATCH BASIN EFFLUENT—GREASE SEWER.										
29	8 a.m. to 8 p.m.	1.53	1360	1320	40	426	275	151	175	46	360
29	8 p.m. to 30, 8 a.m.	1.60	1400	1320	80	384	351	33	170	70	340
30	8 a.m. to 8 p.m.	2.26	880	840	40	511	312	199	178	94	490
30	8 p.m. to 1, 8 a.m.	0.61	520	480	40	545	470	75	255	102	390
	"RED" SEWER EFFLUENT.										
29	8 a.m. to 8 p.m.	1.68	1120	1080	40	313	219	94	116	52	440
29	8 p.m. to 30, 8 a.m.	1.17	156	152	4	52	40	12	32	13	170
30	8 a.m. to 8 p.m.	2.40	440	400	40	283	111	172	69	43	320
30	8 p.m. to 1, 8 a.m.	0.57	48	40	8	26	22	4	84	76	140

APPENDIX XXIII.

Report of Tests Made at Plant of SWIFT AND COMPANY.

June 6 to 10, 1911.

LOCATION. The plant of Swift & Co., with the exception of the hog house and the general office, is located west of Packers avenue, between 40th and 42d streets. The hog plant and allied departments are between Packers and Center avenues, just east of the main plant.

PLANT. In this plant, slaughtering and packing are conducted on a large scale. Cattle, calves, sheep and hogs are killed and prepared as dressed and smoked meats. The by-products are lard, grease, butterine, soap fats and soap, glue, tripe and fertilizer. A hair factory and a wool pulling and scouring plant are also operated. In the bone house hard and steam bone are prepared, hard bone being sold to the button manufacturers, and steam bone utilized in fertilizer. No canning is done here.

There are two cattle houses, the "north" and "east" houses, where slaughtering, and the preparing of dressed meats, is carried on independently.

In general, Packers avenue is the dividing line of the sewer system, the houses to the west sewering to Ashland avenue, and those on the east side to Center avenue.

CAPACITY. The nominal daily capacity was given as follows:

Cattle, (North and East Houses)	2,000
Calves	200
Sheep	3,000
Hogs	3,000

SLAUGHTERING. During the test from June 6th to 10th, the kill was as indicated on the following page.

BLOOD, RENDERING, ETC. The blood is collected, coagulated and filtered, the solid portion being used with the tank room solids (tankage) for fertilizer filler. The liquid portion is evaporated and the residue dried for "stick."

All scraps, offal and condemned animals, together with the skimming and collected sediment from the various catch basins are rendered for grease. The solid tankage left is pressed and dried for

ACTUAL KILL AT SWIFT & CO. PLANT DURING TEST, JUNE 6 TO 10, 1911.

June		6	7	8	9	10
Cattle,	East House	854	413	836	492	242
	North House	823	428	829	484	0
Calves,	East House	617	623	423	149	0
	North House	215	385	122	0	0
Sheep,	East House	2504	2322	2916	3463	3203
	North House	2705	2365	3137	3631	3205
Hogs		2939	2634	4280	2442	4075

fertilizer filler, the liquid being evaporated and the residue used as "stick."

MANURE. All pen manure is said to be swept up, collected and shipped out, to be used as fertilizer, without further treatment. Cattle and calf paunch manure is burned or shipped out for fertilizer. Sheep paunch manure is dried and sold as fertilizer. Hog paunch manure is shipped out. Paunch manure is separated and pressed, but a deal reaches the sewers, being especially noticeable in the 40th street sewer, where two or three men are kept busy all the time cleaning paunch manure from the catch basin. As only a part of the flow of this sewer is diverted to the catch basin, a large quantity of manure enters the Ashland avenue sewer

SEWERAGE SYSTEM. The Swift & Co. plant has five sewer outlets; 40th and 42d streets to Ashland avenue; Packers avenue to the river; and 41st and 42d streets to Center avenue. The 40th street, Packers avenue and the 41st street lines are interconnected, for interchangeable diversion, but the connecting lines are probably too small to divert the entire flow of any one sewer. Most of the sewers are old, and small. The two to Ashland avenue, especially, are inadequate during heavy rains.

For the test, each of the lines was weired to measure the total flow as far as possible. Readings and samples were taken at each weir, and at certain other points. The sampling points were designated A, B, C, D, E, F and G, and are described in that order.

"A"—40TH STREET TO ASHLAND AVENUE.

DESCRIPTION. The main sewer is a 20-in. tile pipe, emptying into the Ashland avenue sewer at 40th street. The departments drained are:

North Beef House,
Barns,
Shops, machine, paint, carpenters, etc.
Refrigerator Plant,
Feather Factory,

Crematory,

Libby, McNeill & Libby.

CATCH BASINS. The main catch basin is at one side of 40th street, about a block east of Ashland avenue. A timber gate, in a manhole on the main, diverts the greater part of the flow through the catch basin, the overflow passing over the gate. The catch basin is brick, built entirely below the ground level. The inside dimensions are 25 ft. long by 10 ft. wide, with brick baffle dividing the basin longitudinally, making the total length of flow 50 ft. This is tight, except at the end opposite the inlet, where it acts as an underflow baffle.

Besides the central baffle there are six brick underflow baffles, each 10 in. thick, rising 30 in. above the bottom. On the effluent side there are three wire screens of 1-in. mesh, 6 ft. apart, which clog very rapidly, being cleaned one at a time by being pulled out of water and shaken. The collected matter drops back into the basin. At the effluent end, below the last screen, is an overflow baffle 5 ft. high, made of loose planks in guides, so that the level may be lowered if necessary. During the test, the depth of water varied from 5 ft. to 6 ft., depending on the flow and the amount of head lost through the screens.

A crew of three men is kept busy cleaning out the screens and removing the settled material, which is almost entirely paunch manure.

Besides the main basin, there are five others on the line for retaining grease and manure. Four of these are at the North Beef House, and the fifth is at the stables.

WEIR. Only one weir was built on this line, a 21-in. wooden weir, without end contractions, placed in a 42-in. diameter manhole on 40th street, below the catch basin.

READINGS AND SAMPLES. Readings and samples were started here at noon, June 6, and continued to 4 p. m., June 10. Up to noon, June 9, composite samples were collected, extending over 2-hour periods during the day, and 4-hour periods during the night, individual portions being taken every 20 minutes. Beginning at noon, June 9, individual portions were collected once an hour, the composites extending from noon to 8 p. m. June 9; 8 p. m. to 8 a. m., June 10; and 8 a. m. to noon, June 10.

ANALYSES. Only the total suspended matter was determined for each individual sample. The oxygen consumed was tested on a few. For complete analysis, composites were made of 12-hour periods, weighted by the flow. The analyses of composites and the average flows are given in table 175.

TABLE 175.

CHEMICAL ANALYSIS OF OUTFLOW OF SWIFT SEWER DISCHARGING AT 40TH ST. INTO ASHLAND AVENUE

June 6 to 10, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Sus-pended.	Organic Nitrogen.	Free Ammonia.	
June											
6	12 M. to 8 p.m.	4.5	936	804	132	323	156	167	22	18	260
6	8 p.m. to 7, 8 a.m.	2.2	198	122	76	96	59	37	9	5	190
7	8 a.m. to 8 p.m.	3.8	940	812	128	296	131	165	75	18	260
7	8 p.m. to 8, 8 a.m.	2.1	152	122	30	57	44	13	29	6	190
8	8 a.m. to 8 p.m.	4.8	1004	920	84	319	135	184	76	33	300
8	8 p.m. to 9, 8 a.m.	3.1	376	332	44	119	73	46	25	13	230
9	12 M. to 8 p.m.	3.9	812	...	...	303	130	173	56	18	260
9	8 p.m. to 10, 8 a.m.	2.4	164	148	16	94	57	37	21	14	230
10	8 a.m. to 4 p.m.	3.6	996	784	212	210	52	158	50	43	310

SETTLING EXPERIMENTS. In settling experiments on the effluent of the 40th street sewer 75 per cent. of the total suspended solids settled out in 1 hour under quiescent conditions.

"B." 42D STREET TO ASHLAND AVENUE.

DESCRIPTION. Although this 36-in. brick sewer is the largest in the plant, its capacity is greatly overtaxed, as it flows full or under pressure at all times when killing is going on. In a moderately hard rain all the lower cellars are flooded. At other times it becomes choked. It drains the following places:

East beef house, including cattle pens, killing floors, coolers, tank rooms and wool house.

Mooris' beef house catch basin and two toilet sewers.

Lard, tallow and grease refineries.

Soap factory.

Central power station.

Skin house.

Butterine factory.

Commercial fertilizer plant.

Darling glue plant.

Bone and glue house.

Wool house.

CATCH BASINS. At present, the main catch basin is at the hide house on 42d street, a couple of blocks east of Ashland avenue. This is built of concrete, 90 ft. long by 10 ft. 8 in. wide with a water depth nominally ranging from 4 ft. 6 in. to 5 ft. The inlet and outlet at opposite ends are both about a foot under the normal flow line. There are 4 concrete and 3 timber underflow baffles, spaced irregularly. The openings under the concrete baffles are 18 in. deep, and under the timber baffles, 24 in. The only overflow baffle is about 4 ft. back from the outlet, and is 4 ft. high. As this baffle is usually submerged 6 in. to a foot a great deal of solid matter is washed over.

There are six removable wire screens of 1-in. mesh, arranged in pairs, each screen being 4 ft. wide. In cleaning, they are lifted with block and tackle, one at a time, the clogging material being shaken back into the catch basin, and scraped off with wire brushes or brooms. Consequently, at each cleaning a very large part of the material caught on the screens is washed down the sewer.

Two men and sometimes three are required to keep the sewers clean and dredge out the sludge. As it is impossible to drain the basin, all the sludge is bailed out with long-handled shovels and dippers. Practically no grease is collected from this basin, but most of the sludge is utilized for fertilizer filler. A very noticeable odor

of hydrogen-sulphide occurs on Monday morning, when the flow has been small over Sunday.

Below the main catch basin, in front of the Darling Glue plant, a large basin receives the flow from this line except that from the wool house. This basin is covered over, being 10 ft. wide and 4 ft. deep. The flow from the Darling plant empties into the outlet. The basin is in bad repair, receiving no attention. Opposite the Morris Beef House is a small brick catch basin 26 ft. long by 5 ft. 6 in. wide, provided with four underflow baffles, but no screens. There are smaller catch basins at the killing house, soap factory and grease and lard refineries. A special crew of three or four men keeps these smaller basins cleaned out. The large concrete basin taking the flow from the Morris beef plant is described in the Morris report.

WEIRS. As the sewer below the main catch basin flows under pressure, it was impossible to build a weir in a manhole near enough to the outlet into the Ashland avenue main to measure the entire flow. A weir was built, however, in the basin at the hide house, and another in the wool house sewer. Neither received the flow from the glue and bone house, the fertilizer plant in the wool house, nor Darling's. Later a weir was built in the Darling catch basin, and the flow obtained.

The weir in the main catch basin, marked "B," was made in two parts of 2-in. lumber, with a beveled crest of ⅞-in. stock. The last pair of screens were removed and replaced by weirs 4 ft. long, making the equivalent of an 8-ft. weir with two end contractions. Readings were taken 4 ft. above the weir with a hook gage. A 15-in. weir without end contractions was constructed in a manhole on the wool house line, but as the wool house was shut down during the test, readings were not taken until the following week.

In order to deduct the sewage of the Morris beef plant from the total flow of the 42d street sewer, readings and samples were taken once an hour at the weir in the Morris catch basin, designated as "G," and described in the Morris report.

Samples marked "H" were taken from the old catch basin in front of the Darling plant.

READINGS AND SAMPLES. Readings and samples were taken at weir "B" on the 40th street sewer from noon, June 6, to noon, June 10. Beginning at noon June 9, samples were taken at the outlet designated as "H," every 20 minutes, with corresponding readings at "B" (tables 176 and 179).

SETTLING EXPERIMENTS. In settling experiments with fresh samples from the 42d street sewer under quiescent conditions,

TABLE 176.

CHEMICAL ANALYSIS OF OUTFLOW OF 42ND ST. CATCH BASIN. SWIFT AND COMPANY.

June 6 to 10, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspended.	Organic Nitrogen.	Free Ammonia.	
June											
6	12 M. to 8 p.m.	2.4	1336	1012	324	371	237	134	34	33	410
6	8 p.m. to 7, 8 a.m.	0.5	290	170	120	248	180	68	30	18	260
7	8 a.m. to 8 p.m.	2.7	1492	1108	384	448	353	195	144	.42	520
7	8 p.m. to 8, 8 a.m.	1.0	344	216	128	219	163	56	81	19	260
8	8 a.m. to 8 p.m.	4.8	1288	956	332	346	175	171	66	88	590
8	8 p.m. to 9, 8 a.m.	2.6	404	264	140	175	...	...	41	58	450
9	12 M. to 8 p.m.	5.0	1012	...	...	234	199	35	105	32	280
9	8 p.m. to 10, 8 a.m.	2.7	400	...	...	357	190	167	62	40	310
10	8 a.m. to 4 p.m.	4.4	1192	932	260	316	244	72	61	57	460

about 70 per cent. of the total suspended matter settled out in 1 hour.

"C." PACKERS AVENUE TO THE RIVER.

This is an old 12-in. box sewer, taking the flow from the hair factory, overflow from the reservoir and Libby's pickle house. A weir without end contractions, with crest 12¾-in. long, was built in a manhole near the switch tracks at the north end of Packers avenue. The height of the weir above the sewer invert was 10 in.

Samples and readings were taken once an hour from 8 a. m. to 4 p. m., no samples being collected at night (table 177).

"D." 41ST ST. TO CENTER AVENUE.

This is a 24-in. tile sewer on the south side of 41st street, receiving the drainage from part of the hog house (mostly condensing and scald water, wash and pickle water), refrigerator plant, engine room, warehouses, general office and some of the Libby toilets. Readings were taken over a 24-in. weir with two end contractions, built in the last manhole before the line joins the Morris hog house sewer. Samples and readings were taken once an hour from 8 a. m. to 4 p. m. (table 178).

"E." 42D ST. TO CENTER AVENUE.

DESCRIPTION. This 24-in. tile sewer receives nearly the entire flow from the hog house, including the killing and cutting floors, and the boiler and ice-machine rooms. The flow from the hog house, itself, passes through a concrete catch basin, while that from the boiler and ice-machine rooms is by-passed in a 10 by 12-in. box sewer, joining the main line in a manhole below the catch basin.

CATCH BASIN. The hog house catch basin is built of concrete, 90 ft. long by 7 ft. wide, with a flow depth of about 3 ft. 9 in. There are 5 concrete underflow baffles, 15 ft. apart, each having a flow space 12 in. deep. Alternating with these are concrete overflow baffles, rising to 6 in. below the normal water surface. At the effluent end are 3 sets of 1½-in. mesh wire screens, sliding in guides, but padlocked.

One man skims off the grease, and removes the sludge with a shovel. The sludge is almost entirely paunch manure, and small trimmings, fairly fresh in appearance.

WEIR AND SAMPLES. A 24-in. weir with two end contractions was built in the manhole at the junction of the two sewers. Samples were taken once an hour from 8 a. m. to 4 p. m. daily. No samples were taken at night (table 179).

SETTLING EXPERIMENTS. In settling experiments made on

TABLE 177.

CHEMICAL ANALYSIS OF OUTFLOW OF PACKERS AVE. SEWER. SWIFT AND COMPANY.

June 6 to 10, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspended.	Organic Nitrogen.	Free Ammonia	
June 6	12 M.	....	988	848	140	255	...	...	...	...	...
7	8 a.m. to 4 p.m.	0.55	250	190	60	260	195	65	7.4	15	170
8	8 a.m to 4 p.m.	0.76	1424	1318	106	248	155	93	45	32	190
9	8 a.m. to 4 p.m.	0.64	196	...	...	256	212	44	46	55	300
10	8 a.m. to 4 p.m.	0.50	240	186	154	154	123	31	26	32	280

TABLE 178.

CHEMICAL ANALYSIS OF FLOW OF SEWER ON 41ST ST. TO CENTER AVENUE. SWIFT AND CO. WITH CORRESPONDING RESULTS AT 42ND ST. CATCH BASIN. MORRIS AND CO.

June 6 to 10, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million. Suspended Matter. Total.	Volatile.	Fixed.	Oxygen Consumed. Total.	Soluble.	Suspended.	Nitrogen as Organic Nitrogen.	Free Ammonia.	Alkalinity as $CaCO_3$.
June											
	41ST ST. SEWER. SWIFT AND CO.										
6	12 Noon	....	364	322	42	267	...	...	...	...	...
7	8 a.m. to 4 p.m.	2.04	340	290	50	276	210	66	41	9	230
8	8 a.m. to 4 p.m.	1.99	460	380	80	301	209	92	79	19	190
9	8 a.m. to 4 p.m.	2.11	508	...	...	125	37	88	28	46	440
10	8 a.m. to 4 p.m.	1.33	322	...	...	142	74	68	49	60	500
	42ND ST. CATCH BASIN. MORRIS AND CO.										
7	10 a.m. to 4 p.m.	0.95	784	706	78	426	369	57	104	36	350
8	8 a.m. to 4 p.m.	1.38	1052	912	140	306	150	156	86	125	540
9	8 a.m. to 4 p.m.	1.56	1308	...	...	313	165	148	53	190	...
9	4 p.m. to 8 p.m.	1.52	592	...	...	285	187	98	82	17	280
9	8 p.m. to 8 a.m.	0.38	202	178	24	98	81	17	34	40	300
10	8 a.m. to 4 p.m.	....	158	150	8	181	122	59	56	37	290

TABLE 179.

CHEMICAL ANALYSES OF MISCELLANEOUS SAMPLES. SWIFT AND COMPANY.

June, 1911.

Date.	Period of Collection.	Flow, c. f. p. s.	Parts per Million.								
			Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity as $CaCO_3$.
			Total.	Volatile.	Fixed.	Total.	Soluble.	Suspended.	Organic Nitrogen.	Free Ammonia.	
June											
	FLOW OF SEWER ON 42ND ST. DISCHARGING TO CENTER AVE. June 8 to 10.										
8	8 a.m. to 4 p.m.	1.33	1088	928	160	335	169	166	92	36	180
9	8 a.m. to 4 p.m.	1.61	916	...	...	302	118	184	73	52	400
10	8 a.m. to 4 p.m.	1.22	780	652	128	260	105	155	57	55	350
	OUTFLOW OF FINAL 42ND ST. CATCH BASIN "H." June 9 and 10.										
9	8 p.m. to 10, 8 a.m.	2.8	1156	792	364	241	156	85	...	27	250
10	8 a.m. to 4 p.m.	4.4	992	716	276	225	90	135	...	96	520
	OUTFLOW FROM FERTILIZER HOUSE. SPECIAL SAMPLE. June 8.										
8	3:45 p.m.	....	292	250	42	160	111	49	56	85	290
	OUTFLOW FROM WOOL HOUSE. June 8, 13, 14 and 15.										
8	4 p.m.	....	626	200	426	48	14	34	21	47	200
13	10 a.m. to 4 p.m.	1.4	1316	628	688	243	136	107	59	15	320
14	8 a.m. to 4 p.m.	1.5	1040	456	584	247	141	106	57	20	370
15	8 a.m. to 12 M.	1.8	1260	424	836	214	115	99	56	24	350

the effluent of the 42d street to Center avenue sewer about 30 per cent. of the total suspended solids settled in 1 hour under quiescent conditions.

WOOL HOUSE. Readings and samples were taken at the weir in the sewer from the wool house on June 13, 14 and 15. Samples were collected at 10-minute intervals from 8 a. m. to 4 p. m. only. The composite samples extended over periods of 2 hours. For analysis, laboratory composites for each day were made up, proportioned to the flow (table 179).

APPENDIX XXIV.

Report of Tests at Plant of WESTERN PACKING COMPANY.

June 26 to 28, 1911.

PLANT. The Western Packing Company, located at 38th place and Morgan street, conducts a general slaughtering and packing business. Fresh and pickled meats are prepared, as well as tripe, oleo stock, lard, inedible grease and fertilizer. No smoked meat, butterine or sausage are manufactured. The hides are cured before selling, but hog hair and casings are sold green.

CAPACITY. The nominal daily capacity of the plant was given as:

Cattle	150
Calves	25
Sheep	150
Hogs	1,200

On the second day of the test, the kill was said to be about up to capacity, but on the first and third the kill was light.

PENS. The pens are small, storing only a part of the daily kill. The manure is swept up, loaded into cars, and shipped out for fertilizer. However, the pens drain directly to the river, so a considerable quantity of manure is probably flushed out by rains.

PAUNCH MANURE. The greater part of the paunch manure is said to be used for fertilizer. Some is at times shipped out with the pen manure. The paunch manure press is operated intermittently, whenever enough manure has accumulated in the separator tank, usually a couple of hours a day. When the kill is light it may not be used at all. The paunch manure overflow is not settled, so that a large amount of manure escapes into the river.

BLOOD, RENDERING, ETC. The blood is collected and coagulated, but not filtered. The cooked blood is used entirely as fertilizer stock. Scraps, offal, etc., are rendered for grease, the solid tankage being pressed and the tank liquor evaporated for stick.

SEWERS. There are four drains from the plant. Two of these, the scald water and the paunch manure overflow drains both 8-in. tile pipe, empty directly into the river. The scald water outlet runs more or less continuously during the killing. The paunch manure overflow runs only when the manure press is operated. The drainage from the killing and cutting floors, and the tank room, including

floor water, blood, grease, etc., goes into the main catch basin. A 20-in. box sewer takes the flow from the oleo, tripe room and pickled meat cellars, and some of the wash water. This empties into the second catch basin. The overflow from the reservoir and the ice machine runs directly to the river and was not sampled.

CATCH BASINS. There are nominally three timber catch basins, of which two are of no account. The first in line is of timber, built in two parallel sections, each 3 ft. wide. The total length of flow is 150 ft., with a normal depth of flow averaging about 4 ft. 3 in. The inlet is below the surface at the east end of the first tank. Between the two tanks, at the west end, is a 12-in. tile pipe at the surface. The 12-in effluent pipe at the surface of the east end of the second tank drains into the second catch basin. There are 18 sets of overflow and underflow baffles. The overflow baffles are downstream, 4 ft. 2 in. high, with a space below the scum boards of 24 in.

The second catch basin has one side formed by the timber dock along the river. This basin is 72 ft. long by 11 ft. wide, the effluent flowing from the west end through the dock. This basin apparently is never cleaned, the sludge filling it nearly to the surface of the water. There are no screens in either basin.

The first basin was also badly in need of cleaning, containing 12 to 18 in. of sludge on the bottom. This sludge has always been black and septic on inspection.

WEIRS AND SAMPLES. A weir 3 ft. long with end contractions, was built on the last overflow baffle of the first catch basin. Another weir, 1.8 ft. long, was put in the mouth of the box sewer entering the second catch basin. None of the smaller outlets were weired (table 181).

Regular samples were taken at 20-minute intervals at the outlet of the first catch basin, the outlet of the box sewer, and of the final combined effluent on entering the river. The paunch manure and scald water outlets were not sampled regularly owing to the difficulty of access. Occasional samples were taken during the day.

TABLE 180.

NOMINAL ELEMENTS OF MAIN CATCH BASIN. WESTERN PACKING CO.

Capacity 3190 Cu. Ft.

Flow, c. f. p. s.	Period in Basin, Min.	Av. Velocity, Ft. per Min.	Max. Velocity, Ft. per Min.
0.10	531	0.28	0.6
.25	212.5	0.71	1.5
.50	106	1.4	3.0

TABLE 181.

CHEMICAL ANALYSIS OF OUTFLOWS FROM WESTERN PACKING COMPANY.

June 26, 27, 28, 1911.

Source.	Composite No.	Date June.	Time of Collection.	Flow, c.f.p.s.	Parts per Million.								
					Suspended Matter.			Oxygen Consumed.			Nitrogen as		Alkalinity in $CaCO_3$.
					Total.	Volatile.	Fixed.	Total.	Soluble.	Suspended.	Organic Nitrog'n.	Free Amm'a.	
Catch-Basin Effluent "A"	I.	26	12 to 4 p.m.	0.10	608	536	72	329	238	91	110	31	400
	II.	27	8 a.m. to 4 p.m.	0.28	924	760	154	355	214	141	100	38	400
	III.	27	4 p.m. to 5 p.m.	0.42	2160	2000	160	556	302	254	185	23	360
	IV.	28	8 a.m. to 10 a.m.	0.12	876	676	200	327	156	171	89	35	520
Wash Water "B"	I.	Time same as above	Time same as above.	0.41	136	132	4	62	30	32	22	13	180
	II.			0.56	320	252	68	205	136	69	78	24	190
	III.			0.76	284	220	64	282	114	168	50	14	210
	IV.			0.58	220	190	30	87	33	54	52	19	230
Final Combined Effluent	I.	Time same as above	Time same as above.	0.51	356	304	52	177	111	66	67	19	250
	II.			0.84	608	480	128	257	108	149	71	25	270
	III.			1.18	1080	1060	20	372	227	145	119	15	...
	IV.			.70	344	300	44	168	102	66	58	22	250
Paunch Manure	I.	27	11 a.m.	....	1800	1320	480	893	334	559	176	29	1210
Scald Water	I.	26	4 p.m.	....	2904	2516	388	791	316	475	481	56	560
	II.	27	3 p.m.	....	4800	4000	800	1065	432	633	662	90	620

APPENDIX XXV.

Methods of Analysis and Sampling.

GENERAL. In general, the "Standard Methods of Analysis" (second edition) recommended by the American Public Health Association, were followed, except as indicated herein.

ORGANIC NITROGEN. The sample was digested with concentrated sulphuric acid, diluted with water, neutralized with sodium hydrate, and made up to a definite volume. After standing over night, an aliquot portion was Nesslerized. The free ammonia, determined separately, was subtracted to give the organic nitrogen. The nitrogen in sludge was determined in substantially the same manner.

FREE AMMONIA. Free ammonia was determined by distillation and subsequent Nesslerization.

NITRATES. Nitrates were determined by the aluminum reduction method.

OXYGEN CONSUMED. The oxygen consumed was determined by digesting the acidified sample with standard potassium permanganate solution in the steam bath for 30 minutes, and retitration with standard oxalic acid.

SUSPENDED MATTER. Suspended matter was determined by the Gooch crucible method. A known volume of the liquid was filtered through a thin mat of finely divided asbestos fibre, deposited in the bottom of a perforated porcelain crucible. The increase in weight after drying was noted.

FATS. The fat content of sewage and effluents was determined by evaporating the acidified sample to dryness, and extracting the fat with ether. In determining the fat in sludges, acidification was omitted in most cases, the ether extraction being made directly on the dried residue. In special cases noted, the sludge was acidified.

BIOLOGIC OXYGEN CONSUMPTION. (BIO-CHEMICAL OXYGEN DEMAND.) The saltpeter method used was developed by Dr. Arthur Lederer, and is described in detail in the Journal of Infectious Diseases, May, 1914. The method, in brief, consists in the addition of definite amounts of saltpeter (sodium nitrate c. p.) to the sample, incubation with the addition of metheylene blue as an indicator for 10 days at 20 deg. C., and the determination of the residual nitrite-nitrate. From an extended series of tests, it has

been found that 2 molecules of the nitrate yield approximately 5 atoms of available oxygen. Knowing the difference between the amount of nitrate added to the sample and that remaining after incubation, the oxygen demand can be readily calculated. Where necessary (as in sprinkling filter effluents), the total available oxygen in the original sample is also determined and a correction made in the calculation.

SPECIFIC GRAVITY. The specific gravity of sludges was determined by filling a flask of known capacity and weighing. Where necessary to fill voids in the mass, water was added in known amount, and correction made in computing the results.

PER CENT. MOISTURE. The moisture content of sludges and screenings was obtained by noting the loss of weight after drying over the steam bath.

METHOD OF SAMPLING. In all routine sampling, composites were made of 125 c. c. portions taken every hour. For special tests the procedure was changed to meet conditions. Owing to the wide variation in strength of the day and night sewage, two separate samples covering the heavy day and the weak night sewage were analyzed. The following table indicates the sampling schedule followed for the crude sewage:

SAMPLING SCHEDULE—CRUDE SEWAGE.

Date		Day Sewage		Night Sewage		Remarks
From	To	First Sample	Last Sample	First Sample	Last Sample	
Oct. 1, 1912	Jan. 1, 1913	8 a. m.	7 p. m.	8 p. m.	7 a. m.	Daily
Jan, 1, 1913	Feb. 1, 1913	7 a. m.	10 p. m.	11 p. m.	6 a. m.	Daily
Feb. 1, 1913	Jan. 1, 1914	8 a. m.	10 p. m.	11 p. m.	7 a. m.	Bi-Daily
Jan. 1. 1914	Date	No samples—grit chamber effluent only.				

Weighted averages to cover the 24 hr. were also made.

Up to January 1, 1913, one composite covering the entire 24 hr. was taken for the grit chamber and tank effluents. Thereafter, "day" and "night" samples were taken for all devices, allowance being made in the tank samples for the nominal detention period in each case. After January 1, 1914, no samples of crude sewage were taken, as the grit chamber effluent was practically identical in composition. Daily samples of the various effluents were taken up to February 1, 1913, and after that bi-daily composites were made. Sunday samples were, however, kept separate and were omitted after January 1, 1914.

The method of taking samples for the biologic oxygen consumption tests is outlined in Chap. XV.

Samples of sludge and scum for analyses were taken from the tanks, either when cleaned, or at stated intervals when cleaning was infrequent. Sludge samples were collected by lowering into the sludge mass a bottle attached to a stick and plugged by a stopper.. The stopper was then withdrawn by a cord, allowing the sludge to flow in without catching any of the supernatent liquor. A number of samples at various depths were always taken to insure representative composites.

METHOD OF SLUDGE AND SCUM MEASUREMENT. Sludge was measured *in situ* in the tanks by the method devised by Mr. H. B. Hommon at Gloversville, N. Y. A wide-mouthed bottle, with stopper in place, was attached to a calibrated rod and lowered into the tank to a definite depth. The stopper was withdrawn allowing the bottle to fill. The bottle was then lifted and examined. This operation was repeated until the sludge line was closely located. This method was not wholly satisfactory, as it partly ignores the consistency of the sludge other than is visual. In cleaning the Dortmund tanks where the sludge was not entirely drawn out, the amount removed as calculated from the difference between measurements before and after cleaning was much smaller than would be supposed, due to the stirring and thinning of the sludge in the process of withdrawal. The residual sludge doubtless compacted again slowly after cleaning was completed, but the net result indicated a smaller accumulation of sludge than was actually secured. This tendency was more marked for tanks frequently cleaned and probably accounts largely for the lower average sludge accumulation noted for tank C, the true rate probably being somewhat higher. In the spring of 1914, samples of sludge were taken from the tanks both before and after cleaning, so that variations in moisture content could be traced and correction made.

Scums were ordinarily measured by running onto a sludge bed and noting the depth, or if small in amount, a calibrated can or barrel was used.

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